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A STUDY OF THE INCIDENCE OF DISEASE IN A WHALING EXPEDITION TO THE ANTARCTIC PELAGIC WHALING GROUNDS 1946-7

BY

R. A. M. CASE

From the Royal Naval Physiological Laboratory

Whaling is at present an occupation of some economic importance; and the present world fat shortage, coupled with a growing interest in the utilization of whale meat for human food, makes it likely that more people will be so engaged during the next few years. At present, about ten or twelve fleets, each with a complement of some five hundred men, visit the Antarctic pelagic whaling grounds each year.

Each fleet may be expected to carry at least one medical officer, and presumably this has been done for many years, but there seems to be a scarcity of information in the literature about the medical aspects of whaling.

During the *Balaena* expedition of 1946-7, attention was drawn to the problem of sepsis amongst certain classes of workers, and the ship's Medical Officer, Dr. Jamis Hutchison, consulted me on many occasions about this problem.

The *Balaena* expedition was probably unique in whaling history in that it had on board a laboratory in which biochemical, physiological, and bacteriological investigations could be undertaken. The bacteriology was of limited scope, for when the expedition sailed it was not realized that one of the major problems confronting the research team would be bacteriological in nature, and the laboratory had to be partly transformed at sea. Nonetheless, certain findings of some importance did emerge from these bacteriological studies (Case, 1947).

Since attention had been drawn to the problems of sepsis, it was considered worth while analysing the whole of the available hospital data from the *Balaena* sick bay, and this information was willingly placed at my disposal by Dr. Hutchison. The following work is the result of this analysis, with a discussion of the possible implications, and a report of some of the medical work carried out in the laboratory. It is essentially a " post-mortem " study of the data, not the outcome of a piece of planned research, so many shortcomings are apparent in the method of collecting and classifying the material, but the study is offered as a " pilot " investigation in the hope that it will be followed up by subsequent investigators, and as a record of data for subsequent comparison.

The Technique of Whaling

Before embarking upon a consideration of the data, it will be convenient to outline the main operations that took place during the whaling expedition.

The voyage lasted for thirty-three weeks. Eleven weeks of this time were spent in reaching and returning from the whaling grounds, and twenty-two weeks in whaling. Four of these weeks were devoted to chasing sperm whales (*Physeter cotodon*), and the remainder of the time to taking baleen whales (*Balaenoptera musculus* and *B. physalus*, the Blue and Fin whales). These twenty-two weeks will, for the purpose of this communication, be treated as one homogeneous period of whaling.

The whaling took place in an area lying roughly between 55° and 65° South and 40° and 115° East; and, altogether, about 2,500 whales were taken.

During the period of transit to and from the whaling grounds, the catchers assigned to the factory ship were for the greater part of the time sailing independently, but a part of their complement (mainly gunners) was carried on the mother ship. During the whaling period the catchers, now carrying their full complement, would come alongside every two or three days for bunkering.

This meant that during the transit period, the facilities for hospital attendance of the catcher crews would be in no way comparable with those of the complement of the mother ship; and, even during the whaling period, there would be a tendency to more infrequent visits to hospital, or, perhaps, an

attendance for only the less trivial complaints. Allowance will be made for this difference when considering the statistics of attendance.

The factory ship carried the ship's crew, which consisted of the officers, seamen, engineers, and firemen; and also the deck workers and factory operatives. The duties of the latter two groups were to deal with the whale carcase from the time that it was hauled on board until it was finally processed. A considerable degree of interchangeability between these two groups existed, and for the purposes of the present study it is fairer to treat them as one group.

Thus the total complement can be divided into three classes: the catcher crews, who spend most of their time away from the factory, and only handle whole whale carcases soon after death; the factory ship's crew, who are concerned almost entirely with the sailing and organization of the vessel; and the factory and deck workers, who have to handle, dismember, and process the carcases.

The whale was hunted by the catchers, and was shot by a harpoon, the head of which carried a charge of black powder. When dead, the carcase was hauled alongside the catcher and inflated with air to increase its bouyancy. It was then either cast adrift, marked by a flag on the end of a pole, whilst the catcher sought fresh prey; or else made fast alongside and taken back to the factory ship. Here the carcase was towed astern until its turn came to be hauled up and processed.

A carcase might have been dead for anything up to thirty-six hours when processed, but a regulation forbids the Master to allow the catchers to take more whales than the factory can deal with in this space of time. There is an exception to this rule, however, for when a tanker came alongside, an event that occurred four or five times during the season, whales were used as fenders between the two vessels, and would sometimes remain there for several days. At the end of this time they were brought up and flensed, the blubber being utilized, and the remainder of the carcase was then jettisonned. The carcase was in an advanced state of decomposition by this time, and was both offensive to handle and a possible source of infection to those handling it.

The Dutch whaling expedition in 1946-7 made a practice of flensing their fender whales before they were used, and then allowing the flensed carcase to drift away after use. The handling of decomposed material thus was obviated. This method seems worthy of consideration and further investigation.

From its position astern, the whale was hauled up the slipway and flensed, a process in which the thick coating of blubber is sliced with special knives and then stripped from the carcase with wire ropes attached to power driven winches. The pieces of blubber were further subdivided and fed into boilers for the extraction of the oil. The rest of the carcase was then hauled farther forward and the meat cut from the bones. Usually this meat was fed into a further series of boilers to recover the oil, and the extracted residue dried to make meat meal. The bones were also cut into pieces and the oil extracted.

This description refers only to the general whaling routine and does not apply to the production of meat for human consumption, where special arrangements were made, and where special techniques are under consideration by both the whaling company and the appropriate authorities.

During these processes the spongy wooden deck became covered with a thick film of blood, fat and faeces, and since whaling went on by day and night, adequate washing down could only take place on the infrequent occasions when the weather or scarcity of whales interfered with whaling operations. The deck is also the deck-head of the factory, and in areas is kept quite warm by wild heat from below. Splinters from this deck could be a dangerous vector of infection.

Hospital Organization

The hospital was situated on board the factory ship, and usually there were two periods of surgery hours per day, morning and evening. In addition, accidents were treated at once at any time. Officially one medical officer was carried, but on this voyage assistance was available from a medically qualified member of the research team.

In my opinion it is highly desirable that an expedition of this nature should carry two medical officers, since in addition to the medical work of an ordinary ship's surgeon, there are the hazards of quite a large factory to cope with. Further, surgery has to be undertaken, and the employment of an untrained anaesthetist is very unsatisfactory if good results are to be obtained.

When a patient reported at the hospital, a card was filled in with the details of the sickness etc. For the purposes of the statistical analysis, one report of sickness counted as one attendance, irrespective of the number of subsequent visits for the same illness, and was, of course, recorded on the date of the first visit.

Classification

In the analysis, the diseases were grouped in an arbitrary manner in fourteen classifications. These are arranged for convenience in order of the magnitude of incidence, and will be referred to as columns

one to fourteen. Occasionally a disease might appear in two classifications, for example suppurative otitis media would appear under the columns "suppurative lesions" and "diseases of the ear, nose, and throat." Since in these studies little emphasis is laid on the total morbidity figures, but on the column morbidity figures, this double entry does not invalidate the conclusions to be drawn.

Classification of diseases

The arbitrary classification adopted is shown in Table I. These groups will be referred to by the column number, both in the text and in subsequent tabulations.

TABLE I

THE CLASSIFICATION OF DISEASE ARRANGED IN DESCENDING ORDER OF MAGNITUDE OF INCIDENCE

Column number	Disease classification
1	Suppurative lesions
2	Traumatic conditions, including fractures, without sepsis
3	Diseases of the skin
4	Alimentary disorders other than diarrhoea
5	Diseases of the ear, nose, and throat
6	"Rheumatic" conditions
7	Diseases (including foreign bodies) of the eye
8	Venereal diseases, all types
9	Diseases of the upper respiratory tract
10	Burns and scalds
11	Dental conditions
12	Disorders of the central nervous system (organic and functional)
13	Diarrhoea
14	Miscellaneous disorders not included in the above groups

Classification of complement

The classification has been made into three groups on the lines previously discussed, and is shown in Table II. These groups will be referred to subsequently as A, B, and C.

TABLE II

CLASSIFICATION OF THE EXPEDITION'S COMPLEMENT

Group	Description	Number of men
A	Deck and factory workers	224
B	Factory ship's complement	142
C	Catchers' complements	174
	Total complement	540

Division of the season

The division is shown in Table III.

TABLE III

DIVISION OF SEASON

Period	Description	Duration
Transit	Voyage to and from whaling grounds	11 weeks
Whaling	Time spent in catching whales (Sperm, Blue, and Fin)	22 weeks
	Total voyage	33 weeks

Results

Table IV sets out, week by week, the incidence of disease in each group for each column, and also the total morbidity by columns and by weeks. The total classified and unclassified morbidity is also given.

In order to facilitate comparison between the groups, these figures have also been computed as morbidity rate per thousand. These figures are given *in extenso* in Table V, and the totals appended to Table IV.

Figs. 1 to 13 show the weekly morbidity rate per thousand for each group as superimposed histograms.

Table VI sets out the weekly means with standard deviations of the morbidity rate per thousand for each column and group for each period, and also shows the difference of the means of each period for groups A and B. The parameters of significance, using "Student's" (1908) "t" test, are shown for these differences. No such comparison is attempted for group C, since their facilities for hospital attendance were seriously curtailed during the transit period.

Table VII shows the mean of the differences (not the differences of the means) of the weekly morbidity rate per thousand for groups A and B for both periods. Again C is not considered in these

TABL

INCIDENCE OF CLASSIFIED DISEASE WEEK BY WEEK FOR T

Period	Week of voyage	Suppurative lesions 1			Trauma and fractures without sepsis 2			Diseases of the skin 3			Non-diarrhoeic alimentary disorders 4			Diseases of ear, nose, and throat 5			"Rheumatic" conditions 6			Diseases of the eye 7			Venereal disease 8		Diseases of upper respiratory tract 9	
	Group	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	B	C
Transit	1	1	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
	2	1	1	0	1	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0
	3	1	1	0	1	4	0	2	1	0	0	2	0	0	0	1	0	1	0	0	1	0	4	0	1	0
	4	1	2	0	2	2	0	6	3	4	0	1	0	3	0	0	0	0	0	1	0	0	5	1	1	1
	5	1	1	1	6	2	0	3	3	2	0	0	0	2	4	0	1	1	1	2	1	0	2	1	0	0
	6	1	3	0	1	1	0	2	1	0	0	0	0	1	2	0	1	0	1	4	1	0	0	0	0	1
Whaling	7	4	3	1	2	5	0	5	2	0	2	1	0	2	1	1	1	3	0	3	0	0	3	2	2	0
	8	5	1	2	5	2	0	5	1	1	2	0	0	2	1	0	1	0	0	0	1	0	0	0	0	0
	9	4	0	0	3	1	0	4	1	0	3	0	1	1	0	0	2	0	0	0	0	0	0	1	1	0
	10	9	2	2	6	2	0	6	2	1	3	0	0	6	1	0	1	0	0	4	1	0	0	0	1	0
	11	16	3	0	4	2	0	4	0	0	3	1	1	9	1	0	1	1	0	2	0	0	2	0	2	0
	12	5	2	1	6	0	0	4	0	2	2	0	0	4	0	0	1	2	0	0	0	0	0	0	0	0
	13	7	1	0	1	0	1	2	0	0	1	0	1	4	2	0	2	2	0	1	0	0	1	1	0	0
	14	7	1	0	6	0	1	5	4	0	3	4	0	2	2	0	6	0	1	2	0	1	1	1	1	0
	15	2	0	0	2	0	1	1	0	0	0	6	2	1	2	0	2	0	0	3	0	0	1	0	0	0
	16	9	4	0	3	2	0	2	1	0	3	1	0	1	0	0	3	0	0	0	0	0	2	0	0	0
	17	5	0	1	3	3	1	2	0	0	3	0	0	3	0	1	0	1	1	0	0	0	0	0	0	0
	18	8	2	0	4	1	0	5	1	0	2	0	0	1	0	0	3	1	1	1	0	0	1	0	0	0
	19	3	0	0	5	0	1	3	0	0	3	2	2	1	0	0	0	2	0	1	1	0	0	1	0	0
	20	4	3	0	5	1	0	5	2	1	4	4	0	0	0	0	2	1	0	2	1	0	1	0	0	0
	21	3	1	0	4	0	0	2	0	0	0	0	0	1	0	0	1	0	0	2	0	0	1	0	1	0
	22	3	2	0	2	1	0	0	3	0	0	0	0	0	0	0	4	1	0	2	0	0	0	0	0	0
	23	5	1	0	4	1	0	5	1	0	1	2	0	0	0	0	3	0	0	1	1	0	0	0	0	0
	24	4	2	0	8	0	0	4	0	0	2	2	0	2	0	0	1	1	0	0	0	0	0	0	1	0
	25	4	4	0	3	2	0	4	2	0	5	2	0	2	0	0	3	0	0	1	0	0	0	0	0	0
	26	5	0	0	6	1	0	5	1	0	5	0	0	1	1	0	1	1	0	2	2	0	1	0	0	0
	27	2	0	1	5	2	0	5	0	1	5	1	2	1	0	0	0	0	0	0	0	0	0	0	0	0
	28	3	1	0	6	1	2	3	0	0	3	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Transit	29	0	0	0	4	2	2	3	0	0	3	1	1	3	0	0	1	0	0	6	2	0	0	0	0	0
	30	1	1	0	0	0	0	0	1	0	0	0	0	1	0	0	1	0	0	0	1	0	3	1	1	0
	31	2	0	0	3	2	0	8	0	1	2	0	0	3	1	0	1	2	0	0	0	0	1	1	0	0
	32	0	0	0	0	1	0	1	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total morbidity (classified)		126	42	9	111	42	9	107	32	13	60	26	11	57	19	3	44	20	5	41	14	1	29	10	13	2
Total morbidity rate per 1,000 (classified)		567·0	298·2	52·2	499·5	298·2	52·2	481·5	227·2	75·4	270·0	184·6	63·8	256·5	134·9	17·4	198·0	142·0	29·0	184·5	99·4	5·8	130·5	71·0	58·3	11·6
Total morbidity		177			162			152			97			79			69			56			47		37	
Total morbidity rate per 1,000		329·2			301·3			282·7			180·4			146·9			128·3			104·2			87·4		68·8	

TABL

SE WEEK FOR THE THREE OCCUPATIONAL GROUPS

Venereal disease 8		Diseases of upper respiratory tract 9			Burns and scalds 10			Dental conditions 11			Disorders of C.N.S. 12			Diarrhoea 13			Miscellaneous conditions 14			Weekly morbidity			Weekly morbidity rate per 1,000			Total weekly morbidity	Total weekly morbidity rate per 1,000
A	B	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C			
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	3	2	4·5	21·3	11·6	6	11·2
0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	7	1	1	31·5	7·1	5·8	9	16·7
4	0	1	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0	10	12	3	45·0	85·2	17·4	25	46·5
5	1	1	0	0	0	0	0	0	0	0	0	0	1	0	1	0	3	0	21	13	7	94·5	92·3	40·6	41	76·3
2	1	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	19	14	5	85·5	99·4	29·0	38	70·7
0	0	0	1	1	0	0	1	0	0	0	0	0	0	0	1	1	0	0	13	8	3	58·5	56·8	17·4	24	44·6
3	2	2	0	1	2	0	0	1	0	0	0	0	1	1	0	2	1	0	27	24	4	121·5	170·4	23·2	55	102·3
0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1	1	23	8	5	103·5	56·8	29·0	36	67·0
0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	19	4	1	85·5	28·4	5·8	24	44·6
0	1	1	0	1	0	0	0	0	0	2	0	0	0	0	0	1	0	1	40	9	4	180·0	63·9	23·2	53	98·6
2	0	2	0	1	1	0	3	0	0	0	0	0	0	0	0	3	1	0	48	12	1	216·0	85·2	5·8	61	113·5
0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2	6	0	24	4	4	108·0	28·4	23·2	32	59·5
1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	2	0	0	21	7	3	94·5	49·7	17·4	31	57·7
1	1	0	0	2	1	0	2	0	0	2	1	0	1	0	0	0	0	0	39	15	4	175·5	106·5	23·2	58	107·9
1	0	0	0	2	0	0	1	1	0	0	1	0	0	0	0	1	0	0	15	6	3	67·5	42·6	17·4	24	44·6
2	0	0	1	0	0	0	2	1	0	0	0	0	0	0	0	3	0	0	29	9	0	130·5	63·9	0·0	38	70·7
0	0	0	0	0	0	0	2	0	0	0	1	0	1	0	0	0	0	0	19	5	4	85·5	35·5	23·2	28	52·1
0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	1	0	0	28	6	2	126·0	42·6	11·6	36	67·0
1	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	17	7	4	76·5	49·7	23·2	28	52·1
0	0	0	0	1	0	0	2	0	0	0	0	0	0	0	0	2	1	0	30	14	1	135·0	99·4	5·8	45	83·7
1	0	0	1	0	1	0	0	0	0	1	0	1	0	0	0	0	0	0	16	2	2	72·0	14·2	11·6	20	37·2
0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0	1	1	1	15	9	1	67·5	63·9	5·8	25	46·5
0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	20	7	1	90·0	49·7	5·8	28	52·1
1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	27	6	0	121·5	42·6	0·0	33	61·4
0	0	0	0	1	0	0	1	0	0	2	0	0	2	0	0	2	1	0	29	13	0	130·5	92·3	0·0	42	78·1
0	0	0	1	0	0	0	1	1	0	2	1	0	0	0	0	1	0	0	31	8	0	139·5	56·8	0·0	39	72·5
0	0	0	0	0	1	0	2	0	0	0	1	0	0	0	0	0	0	0	20	4	4	90·0	28·4	23·2	28	52·1
0	0	0	0	0	1	0	0	2	0	1	0	0	0	0	0	0	1	0	17	7	2	76·5	49·7	11·6	26	48·4
0	0	0	0	4	1	0	1	0	0	0	0	0	0	0	0	0	2	0	26	8	3	117·0	56·8	17·4	37	68·8
3	1	1	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	7	6	1	31·5	42·6	5·8	14	26·0
1	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0	2	1	0	24	9	1	108·0	63·9	5·8	34	63·2
0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	1	0	0	4	4	0	18·0	28·4	0·0	8	14·9
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0·0	0·0	0·0	0	0·0
29	10	13	2	17	14	2	23	6	2	12	7	4	9	2	3	28	17	4	686	264	76				1,026	
30·5	71·0	92·3	11·6	76·5	99·4	11·6	103·5	42·6	11·6	54·0	49·7	23·2	40·5	14·2	17·4	126·0	120·7	23·2	3087·0	1874·4	440·8					
47		37			33			31			23			14			49			1,026						1,026	
87·4		60·8			61·4			57·7			42·8			26·0			91·1			1908·4							

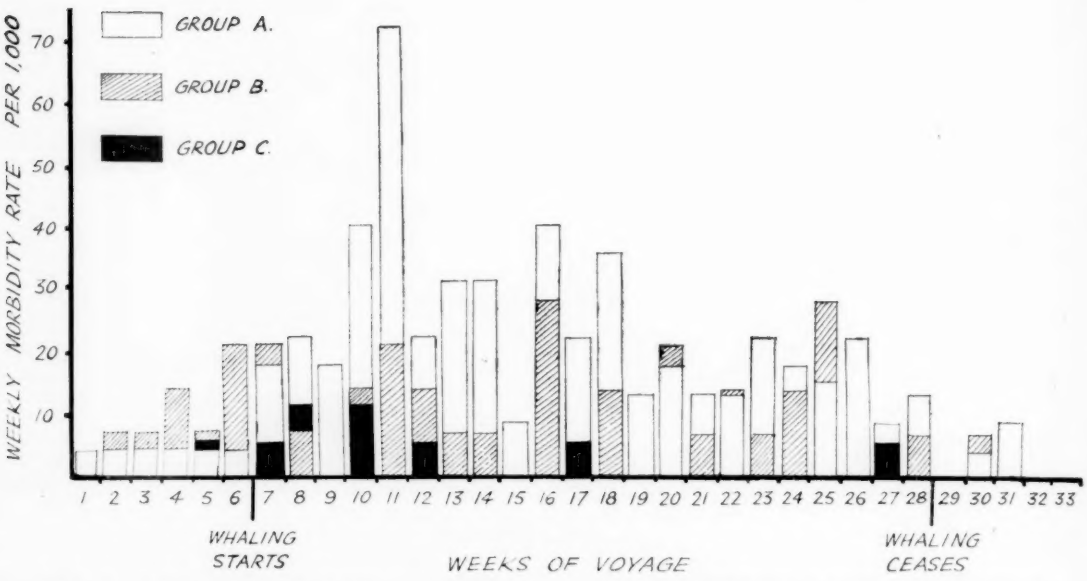

FIG. 1.—Weekly morbidity rate per 1,000 for each group for Column 1 (suppurative lesions).

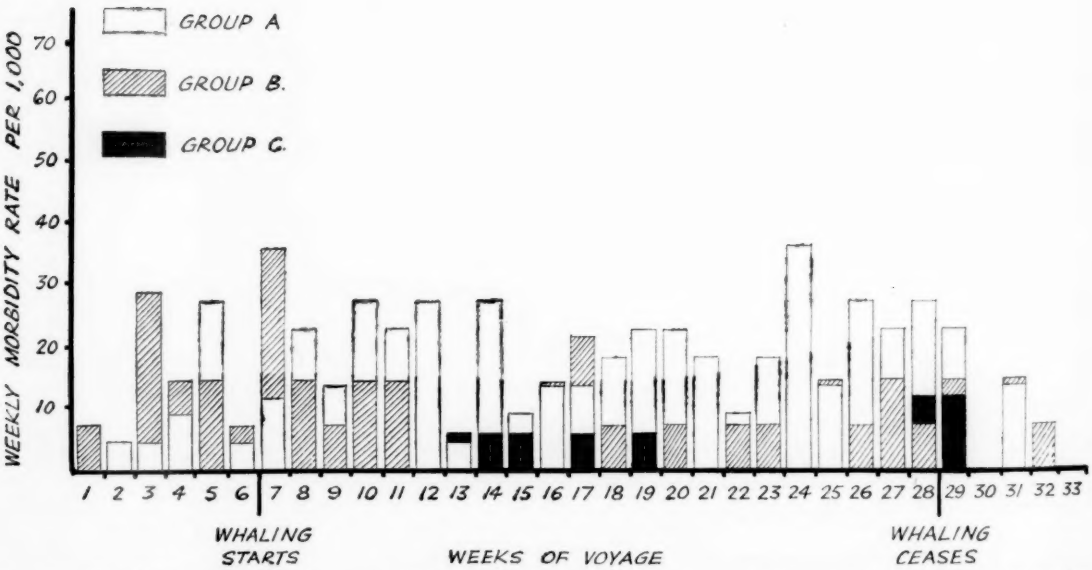

FIG. 2.—Weekly morbidity rate per 1,000 for each group for Column 2 (traumatic conditions including fractures, without sepsis).

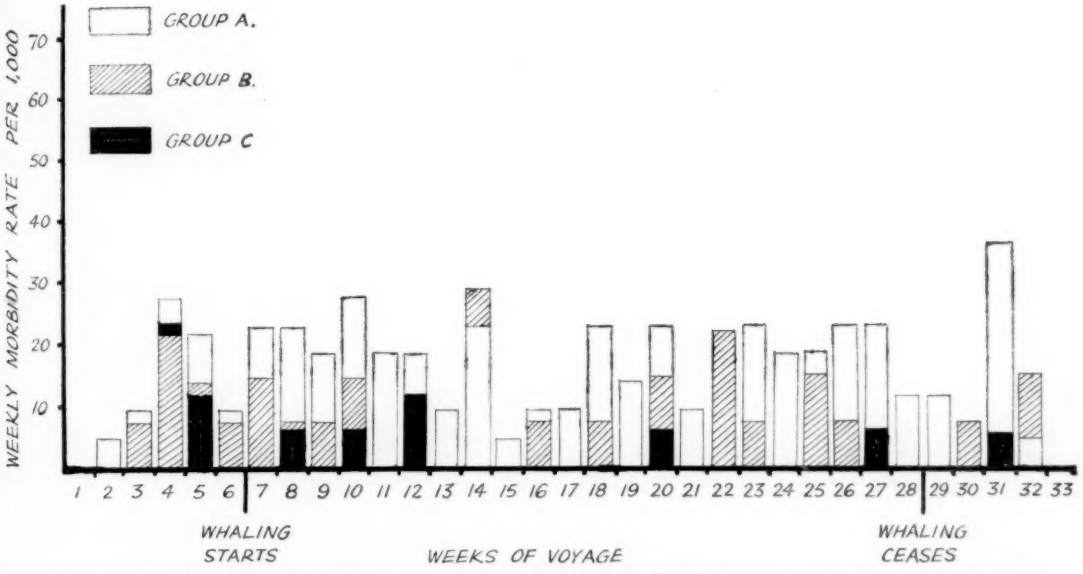

FIG. 3.—Weekly morbidity rate per 1,000 for each group for Column 3 (diseases of the skin).

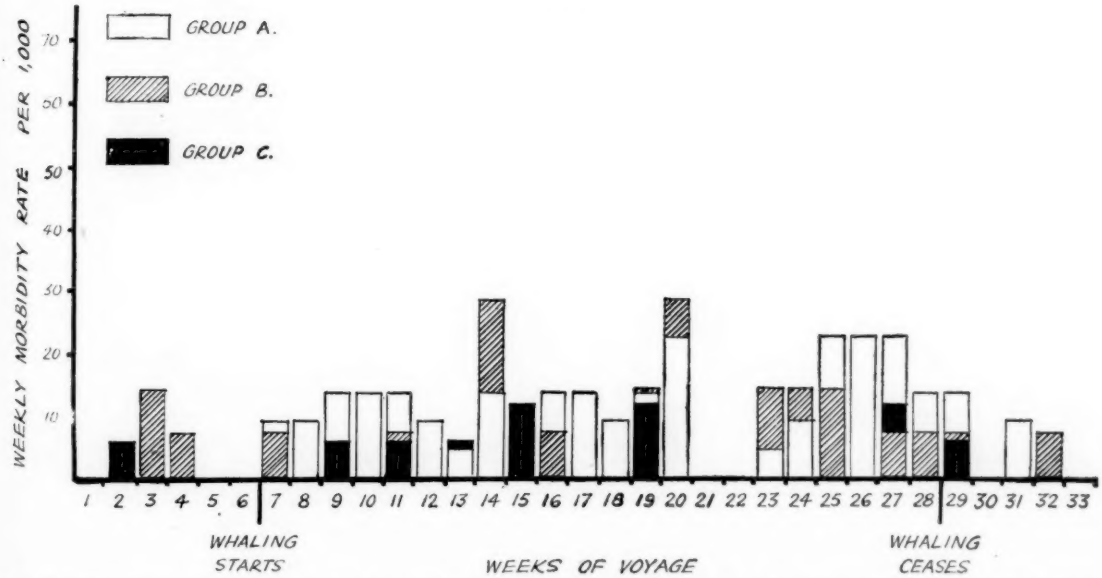

FIG. 4.—Weekly morbidity rate per 1,000 for each group for Column 4 (alimentary disorders other than diarrhoea).

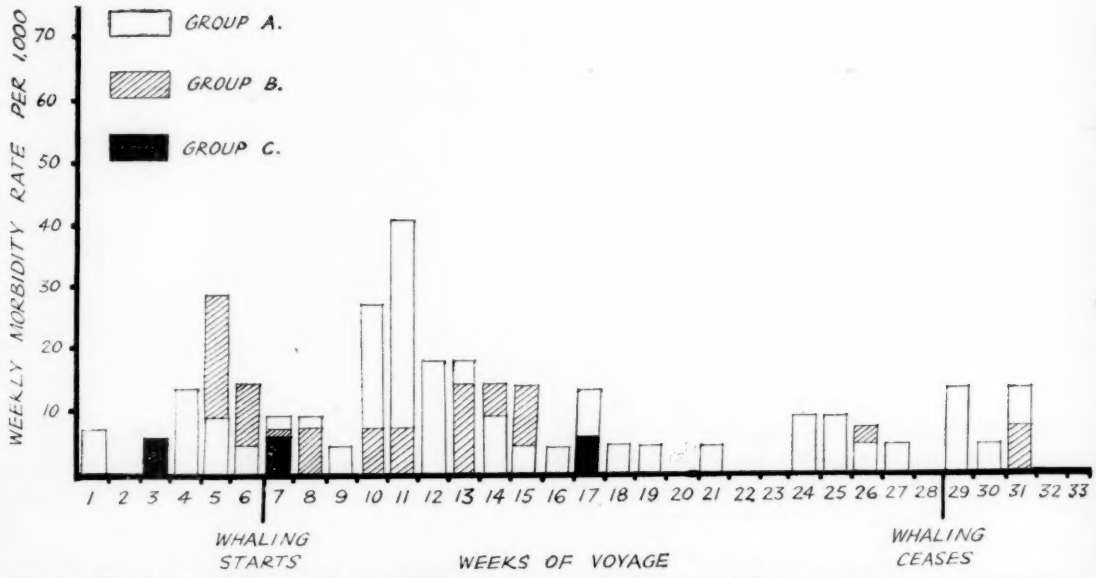

FIG. 5.—Weekly morbidity rate per 1,000 for each group for Column 5 (diseases of the ear, nose, and throat).

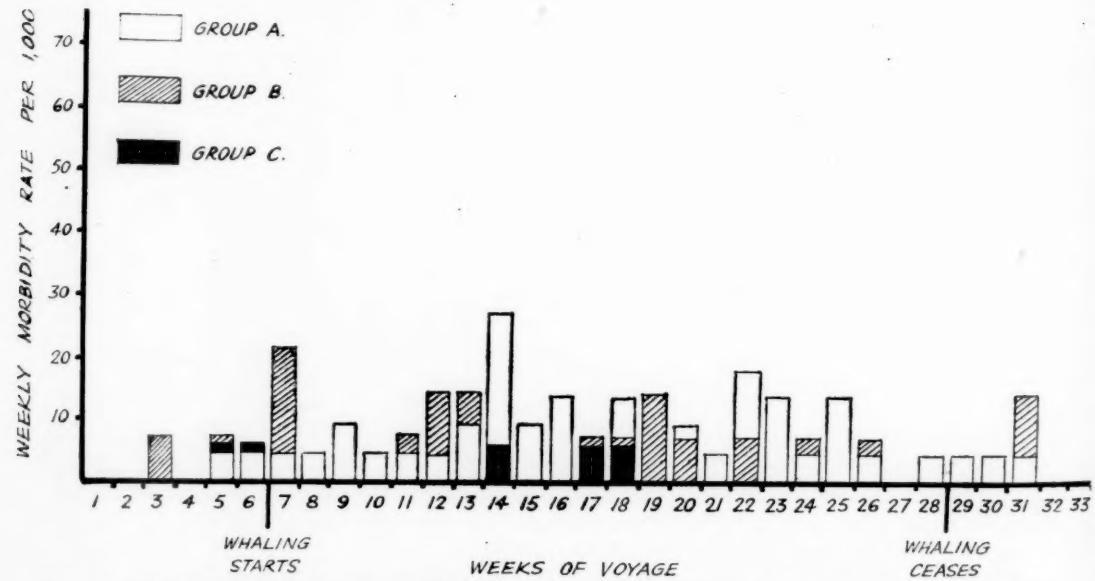

FIG. 6.—Weekly morbidity rate per 1,000 for each group for Column 6 (" rheumatic " conditions).

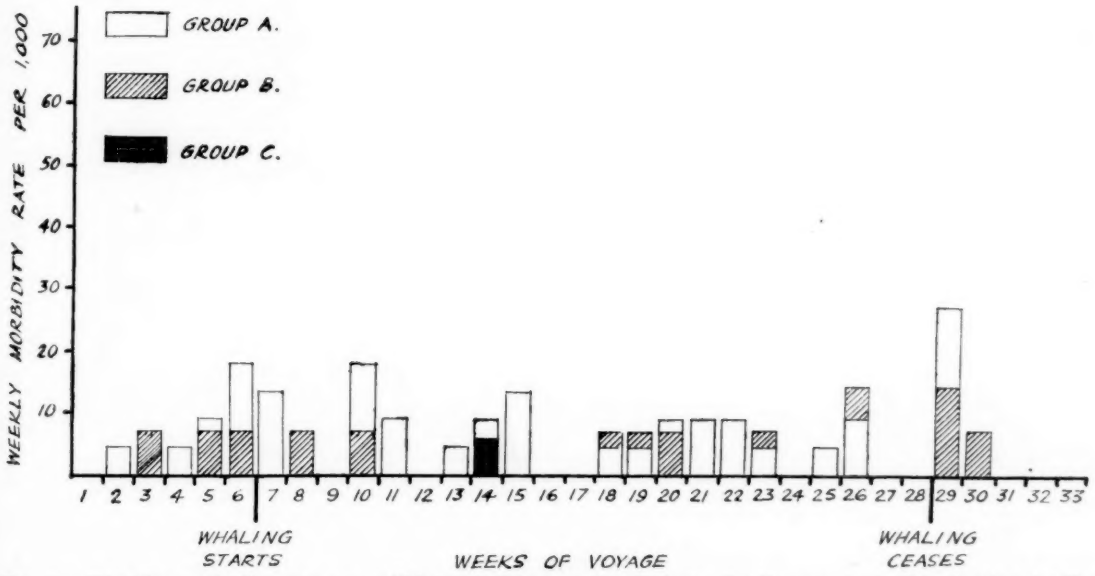

FIG. 7.—Weekly morbidity rate per 1,000 for each group for Column 7 (diseases including foreign bodies of the eye).

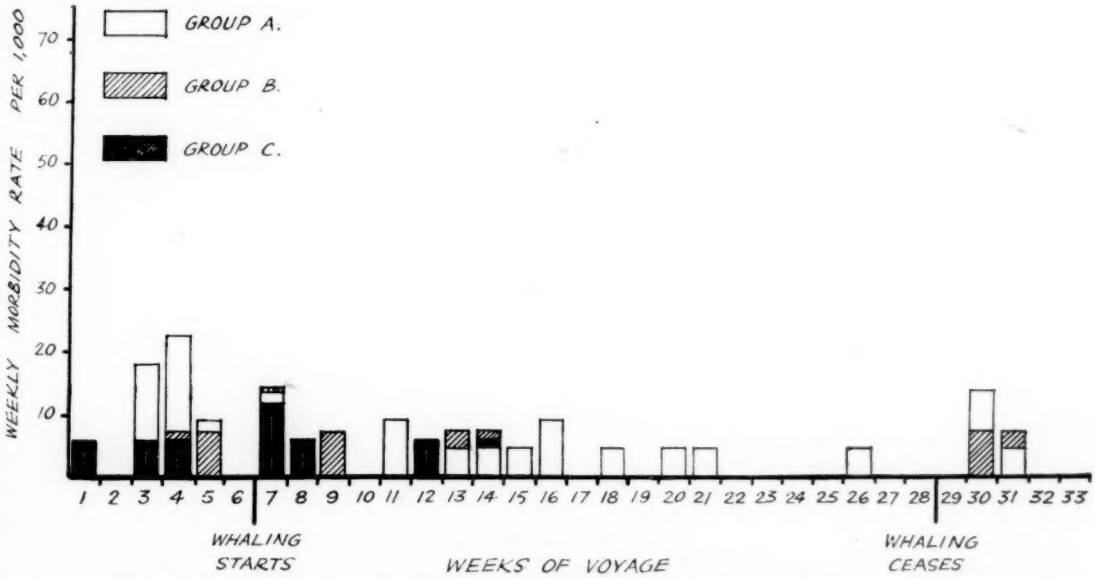

FIG. 8.—Weekly morbidity rate per 1,000 for each group for Column 8 (venereal diseases, all types).

TABL

WEEKLY MORBIDITY RATE P 000 FOR

Period	Week of voyage	Suppurative lesions 1			Trauma and fractures without sepsis 2			Diseases of the skin 3			Non-diarrhoeic alimentary disorders 4			Diseases of ear, nose, and throat 5			"Rheumatic" conditions 6			Diseases of the eye 7		Venereal disease 8	
	Group	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	B	
Transit	1	4·5	0·0	0·0	0·0	7·1	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	7·1	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0
	2	4·5	7·1	0·0	4·5	0·0	0·0	4·5	0·0	0·0	0·0	0·0	5·8	0·0	0·0	0·0	0·0	0·0	0·0	4·5	0·0	0·0	
	3	4·5	7·1	0·0	4·5	28·4	0·0	9·0	7·1	0·0	0·0	14·2	0·0	0·0	0·0	5·8	0·0	7·1	0·0	0·0	7·1	0·0	
	4	4·5	14·2	0·0	9·0	14·2	0·0	27·0	21·3	23·2	0·0	7·1	0·0	13·5	0·0	0·0	0·0	0·0	0·0	4·5	0·0	7·1	
	5	4·5	7·1	5·8	27·0	14·2	0·0	13·5	21·3	11·6	0·0	0·0	0·0	9·0	28·4	0·0	4·5	7·1	5·8	9·0	7·1	7·1	
	6	4·5	21·3	0·0	4·5	7·1	0·0	9·0	7·1	0·0	0·0	0·0	0·0	4·5	14·2	0·0	4·5	0·0	5·8	18·0	7·1	0·0	
Whaling	7	18·0	21·3	5·8	9·0	35·5	0·0	22·5	14·2	0·0	9·0	7·1	0·0	9·0	7·1	5·8	4·5	21·3	0·0	13·5	0·0	14·2	
	8	22·5	7·1	11·6	22·5	14·2	0·0	22·5	7·1	5·8	9·0	0·0	0·0	9·0	7·1	0·0	4·5	0·0	0·0	0·0	7·1	0·0	
	9	18·0	0·0	0·0	13·5	7·1	0·0	18·0	7·1	0·0	13·5	0·0	5·8	4·5	0·0	0·0	9·0	0·0	0·0	0·0	0·0	7·1	
	10	40·5	14·2	11·6	27·0	14·2	0·0	27·0	14·2	5·8	13·5	0·0	0·0	27·0	7·1	0·0	4·5	0·0	0·0	18·0	7·1	0·0	
	11	72·0	21·3	0·0	22·5	14·2	0·0	18·0	0·0	0·0	13·5	7·1	5·8	40·5	7·1	0·0	4·5	7·1	0·0	9·0	0·0	0·0	
	12	22·5	14·2	5·8	27·0	0·0	0·0	18·0	0·0	11·6	9·0	0·0	0·0	18·0	0·0	0·0	4·5	14·2	0·0	0·0	0·0	0·0	
	13	31·5	7·1	0·0	4·5	0·0	5·8	9·0	0·0	0·0	4·5	0·0	5·8	18·0	14·2	0·0	9·0	14·2	0·0	4·5	0·0	7·1	
	14	31·5	7·1	0·0	27·0	0·0	5·8	22·5	28·4	0·0	13·5	28·4	0·0	9·0	14·2	0·0	27·0	0·0	5·8	9·0	0·0	7·1	
	15	9·0	0·0	0·0	9·0	0·0	5·8	4·5	0·0	0·0	0·0	0·0	11·6	4·5	14·2	0·0	9·0	0·0	0·0	13·5	0·0	0·0	
	16	40·5	28·4	0·0	13·5	14·2	0·0	9·0	7·1	0·0	13·5	7·1	0·0	4·5	0·0	0·0	13·5	0·0	0·0	0·0	0·0	0·0	
	17	22·5	0·0	5·8	13·5	21·3	5·8	9·0	0·0	0·0	13·5	0·0	0·0	13·5	0·0	5·8	0·0	7·1	5·8	0·0	0·0	0·0	
	18	36·0	14·2	0·0	18·0	7·1	0·0	22·5	7·1	0·0	9·0	0·0	0·0	4·5	0·0	0·0	13·5	7·1	5·8	4·5	7·1	0·0	
	19	13·5	0·0	0·0	22·5	0·0	5·8	13·5	0·0	0·0	13·5	14·2	11·6	4·5	0·0	0·0	0·0	14·2	0·0	4·5	7·1	0·0	
	20	18·0	21·3	0·0	22·5	7·1	0·0	22·5	14·2	5·8	22·5	28·4	0·0	0·0	0·0	0·0	9·0	7·1	0·0	9·0	7·1	0·0	
	21	13·5	7·1	0·0	18·0	0·0	0·0	9·0	0·0	0·0	0·0	0·0	0·0	4·5	0·0	0·0	4·5	0·0	0·0	9·0	0·0	0·0	
	22	13·5	14·2	0·0	9·0	7·1	0·0	0·0	21·3	0·0	0·0	0·0	0·0	0·0	0·0	0·0	18·0	7·1	0·0	9·0	0·0	0·0	
	23	22·5	7·1	0·0	18·0	7·1	0·0	22·5	7·1	0·0	4·5	14·2	0·0	0·0	0·0	0·0	13·5	0·0	0·0	4·5	7·1	0·0	
	24	18·0	14·2	0·0	36·0	0·0	0·0	18·0	0·0	0·0	9·0	14·2	0·0	9·0	0·0	0·0	4·5	7·1	0·0	0·0	0·0	0·0	
	25	18·0	28·4	0·0	13·5	14·2	0·0	18·0	14·2	0·0	22·5	14·2	0·0	9·0	0·0	0·0	13·5	0·0	0·0	4·5	0·0	0·0	
	26	22·5	0·0	0·0	27·0	7·1	0·0	22·5	7·1	0·0	22·5	0·0	0·0	4·5	7·1	0·0	4·5	7·1	0·0	9·0	14·2	0·0	
	27	9·0	0·0	5·8	22·5	14·2	0·0	22·5	0·0	5·8	22·5	7·1	11·6	4·5	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	
	28	13·5	7·1	0·0	27·0	7·1	11·6	13·5	0·0	0·0	13·5	7·1	0·0	0·0	0·0	0·0	4·5	0·0	0·0	0·0	0·0	0·0	
Transit	29	0·0	0·0	0·0	22·5	14·2	11·6	13·5	0·0	0·0	13·5	7·1	5·8	13·5	0·0	0·0	4·5	0·0	0·0	27·0	14·2	0·0	
	30	4·5	7·1	0·0	0·0	0·0	0·0	0·0	7·1	0·0	0·0	0·0	0·0	4·5	0·0	0·0	4·5	0·0	0·0	0·0	7·1	7·1	
	31	9·0	0·0	0·0	13·5	14·2	0·0	36·0	0·0	5·8	9·0	0·0	0·0	13·5	7·1	0·0	4·5	14·2	0·0	0·0	0·0	7·1	
	32	0·0	0·0	0·0	0·0	7·1	0·0	4·5	14·2	0·0	0·0	7·1	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	
	33	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	

TABL

THE INFLUENC HALING

Period	Column	1			2			3			4			5			6		7	
	Group	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	B	
Transit	M	3·7	5·8	0·5	7·4	9·0	1·0	10·6	7·1	3·7	2·0	2·2	1·0	5·3	5·2	0·5	2·0	2·6	3·9	
	6±	2·7	7·0	1·7	8·8	8·9	3·5	11·6	8·3	7·4	5·9	4·9	2·3	6·0	9·0	1·7	2·4	4·8	4·9	
Whaling	M	23·9	9·4	2·1	19·0	8·7	1·9	16·6	6·7	1·6	11·3	8·7	2·4	9·0	3·6	0·5	8·0	5·1	2·6	
	6	14·1	9·9	3·8	7·8	8·7	3·3	7·1	8·1	3·2	4·1	11·6	4·2	9·7	5·3	1·7	6·5	6·2	4·1	
	d	+ 20·2	+ 3·6		+ 11·6	− 0·3		+ 6·0	− 0·4		+ 9·3	+ 6·5		+ 3·7	+ 1·6		+ 6·0	+ 2·5	− 1·3	
	t	4·7	1·1		3·9	0·1		1·8	0·1		2·3	1·5		1·2	0·7		2·9	1·2	0·8	
	P	<0·001	0·25		<0·001	0·90		0·08	0·90		0·03	0·13		0·22	0·45		0·01	0·22	0·40	

n = A 224
B 142
C 174

TABL

Y RATE P

Diseases of the eye 7		
A	B	C
0·0	0·0	0·0
4·5	0·0	0·0
0·0	7·1	0·0
4·5	0·0	0·0
9·0	7·1	0·0
8·0	7·1	0·0
3·5	0·0	0·0
0·0	7·1	0·0
0·0	0·0	0·0
8·0	7·1	0·0
9·0	0·0	0·0
0·0	0·0	0·0
4·5	0·0	0·0
9·0	0·0	0·0
3·5	0·0	0·0
0·0	0·0	0·0
0·0	0·0	0·0
4·5	7·1	0·0
4·5	7·1	0·0
9·0	7·1	0·0
9·0	0·0	0·0
9·0	0·0	0·0
4·5	7·1	0·0
0·0	0·0	0·0
4·5	0·0	0·0
9·0	14·2	0·0
0·0	0·0	0·0
0·0	0·0	0·0
7·0	14·2	0·0
0·0	7·1	0·0
0·0	0·0	0·0
0·0	0·0	0·0
0·0	0·0	0·0

00 FOR CLASSIFIED DISEASES

Venereal disease 8			Diseases of upper respiratory tract 9			Burns and scalds 10			Dental conditions 11			Disorders of C.N.S. 12			Diarrhoea 13			Miscellaneous conditions 14			Total classified weekly morbidity rate			Total weekly morbidity rate
B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	
0·0	5·8	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	7·1	5·8	4·5	21·3	11·6	11·2
0·0	0·0	4·5	0·0	0·0	4·5	0·0	0·0	4·5	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	31·5	7·1	5·8	16·7
0·0	5·8	4·5	7·1	0·0	0·0	7·1	0·0	0·0	0·0	0·0	0·0	0·0	5·8	4·5	0·0	0·0	0·0	0·0	0·0	45·0	85·2	17·4	46·5
7·1	5·8	9·0	7·1	5·8	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	4·5	0·0	5·8	0·0	21·3	0·0	94·5	92·3	40·6	76·3
7·1	0·0	4·5	0·0	0·0	4·5	7·1	0·0	0·0	0·0	5·8	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	85·5	99·4	29·0	70·7
0·0	0·0	0·0	0·0	5·8	4·5	0·0	0·0	4·5	0·0	0·0	0·0	0·0	0·0	0·0	0·0	5·8	4·5	0·0	0·0	58·5	56·8	17·4	44·6
14·2	11·6	4·5	14·2	0·0	4·5	14·2	0·0	0·0	7·1	0·0	0·0	0·0	0·0	4·5	7·1	0·0	9·0	7·1	0·0	121·5	170·4	23·2	102·3
0·0	5·8	9·0	0·0	0·0	0·0	7·1	0·0	4·5	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	7·1	5·8	103·5	56·8	29·0	67·0
7·1	0·0	4·5	7·1	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	4·5	0·0	0·0	85·5	28·4	5·8	44·6
0·0	0·0	4·5	7·1	0·0	4·5	0·0	0·0	0·0	0·0	0·0	9·0	0·0	0·0	0·0	0·0	0·0	4·5	0·0	5·8	180·0	63·9	23·2	98·6
0·0	0·0	0·0	14·2	0·0	4·5	7·1	0·0	13·5	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	13·5	7·1	0·0	216·0	85·2	5·8	113·5
0·0	5·8	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	9·0	0·0	0·0	108·0	28·4	23·2	59·5
7·1	0·0	0·0	0·0	0·0	0·0	0·0	5·8	0·0	0·0	0·0	0·0	0·0	0·0	0·0	7·1	0·0	9·0	0·0	0·0	94·5	49·7	17·4	57·7
7·1	5·8	0·0	7·1	0·0	9·0	7·1	0·0	9·0	0·0	0·0	9·0	7·1	0·0	4·5	0·0	0·0	0·0	0·0	0·0	175·5	106·5	23·2	107·9
0·0	0·0	4·5	0·0	0·0	0·0	14·2	0·0	4·5	7·1	0·0	0·0	7·1	0·0	0·0	0·0	0·0	4·5	0·0	0·0	67·5	42·6	17·4	44·6
0·0	0·0	0·0	0·0	0·0	4·5	0·0	0·0	9·0	7·1	0·0	0·0	0·0	0·0	0·0	0·0	0·0	13·5	0·0	0·0	130·5	63·9	0·0	70·7
0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	9·0	0·0	0·0	0·0	7·1	0·0	4·5	0·0	0·0	0·0	0·0	0·0	85·5	35·5	23·2	52·1
0·0	0·0	4·5	0·0	0·0	0·0	0·0	0·0	4·5	0·0	5·8	0·0	0·0	0·0	0·0	0·0	0·0	4·5	0·0	0·0	126·0	42·6	11·6	67·0
0·0	0·0	0·0	7·1	0·0	0·0	0·0	0·0	4·5	0·0	0·0	0·0	0·0	5·8	0·0	0·0	0·0	0·0	7·1	0·0	76·5	49·7	23·2	52·1
13·5	0·0	0·0	0·0	0·0	0·0	7·1	0·0	9·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	9·0	7·1	0·0	135·0	99·4	5·8	83·7
0·0	0·0	0·0	7·1	0·0	4·5	0·0	5·8	0·0	0·0	0·0	4·5	0·0	5·8	0·0	0·0	0·0	0·0	0·0	0·0	72·0	14·2	11·6	37·2
0·0	0·0	4·5	0·0	0·0	4·5	0·0	0·0	4·5	0·0	0·0	0·0	7·1	0·0	0·0	0·0	0·0	4·5	7·1	5·8	67·5	63·9	5·8	46·5
0·0	0·0	4·5	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	5·8	0·0	0·0	0·0	0·0	7·1	0·0	90·0	49·7	5·8	52·1
0·0	0·0	13·5	7·1	0·0	4·5	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	9·0	0·0	0·0	121·5	42·6	0·0	61·4
0·0	0·0	0·0	0·0	0·0	0·0	7·1	0·0	4·5	0·0	0·0	9·0	0·0	0·0	9·0	0·0	0·0	9·0	7·1	0·0	130·5	92·3	0·0	78·1
0·0	0·0	0·0	0·0	0·0	4·5	0·0	0·0	4·5	7·1	0·0	9·0	7·1	0·0	0·0	0·0	0·0	4·5	0·0	0·0	139·5	56·8	0·0	72·5
0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	9·0	0·0	0·0	0·0	7·1	0·0	0·0	0·0	0·0	0·0	0·0	0·0	90·0	28·4	23·2	52·1
0·0	0·0	0·0	0·0	0·0	0·0	7·1	0·0	0·0	14·2	0·0	4·5	0·0	0·0	0·0	0·0	0·0	0·0	7·1	0·0	76·5	49·7	11·6	48·4
0·0	0·0	4·5	0·0	0·0	18·0	7·1	0·0	4·5	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	14·2	0·0	117·0	56·8	17·4	68·8
7·1	0·0	0·0	7·1	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	4·5	0·0	5·8	0·0	7·1	0·0	31·5	42·6	5·8	26·0
7·1	0·0	4·5	0·0	0·0	0·0	7·1	0·0	0·0	0·0	0·0	4·5	7·1	0·0	0·0	0·0	0·0	9·0	7·1	0·0	108·0	63·9	5·8	63·2
0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	4·5	0·0	0·0	4·5	0·0	0·0	4·5	0·0	0·0	18·0	28·4	0·0	14·9
0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0

TABL

NFLUENCE

6	
A	B
2·0	2·6
2·4	4·8
3·0	5·1
5·5	6·2
+ 5·0	+ 2·5
2·9	1·2
0·01	0·22

HALING ON DISEASE

7	8			9			10			11			12			13			Total			Unclassified Total
B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	
3·9	0·0	5·7	2·6	1·6	2·9	1·9	1·0	2·9	2·6	1·0	1·2	0·0	0·5	0·8	0·6	0·5	1·6	0·0	1·6	54·0	50·3	13·7	37·9
4·9	0·0	8·6	3·6	2·7	3·0	3·3	0·2	5·4	3·6	0·2	2·1	0·0	1·7	1·8	2·1	1·7	2·3	0·0	2·7	41·5	34·1	12·5	27·3
2·6	0·3	2·9	1·6	1·3	3·1	3·3	0·0	2·0	3·3	0·0	4·1	1·9	0·3	2·1	1·9	0·8	1·0	0·6	0·0	111·3	60·0	13·2	66·4
4·1	1·3	3·8	3·8	3·1	4·3	4·8	0·0	2·7	4·8	0·0	4·1	4·2	1·3	3·6	3·3	2·0	2·6	2·1	0·0	39·5	34·1	11·2	22·0
− 1·3		− 2·8	− 1·0		+ 1·4	+ 1·4		− 0·9	+ 0·7		+ 2·9	+ 1·9		+ 1·3	+ 1·3		− 0·6	+ 0·6		+ 63·3	+ 9·7		+ 26·7
0·8		1·3	0·7		0·1	0·9		0·6	0·4		2·1	1·5		1·1	1·2		0·6	1·0		4·0	0·8		2·9
0·40		0·25	0·45		0·90	0·34		0·52	0·66		0·04	0·13		0·25	0·22		0·52	0·29		<0·001	0·40		0·005

M = mean weekly morbidity rate per 1,000

d = difference of means of whaling and transit periods.
A + means an increase during whaling.

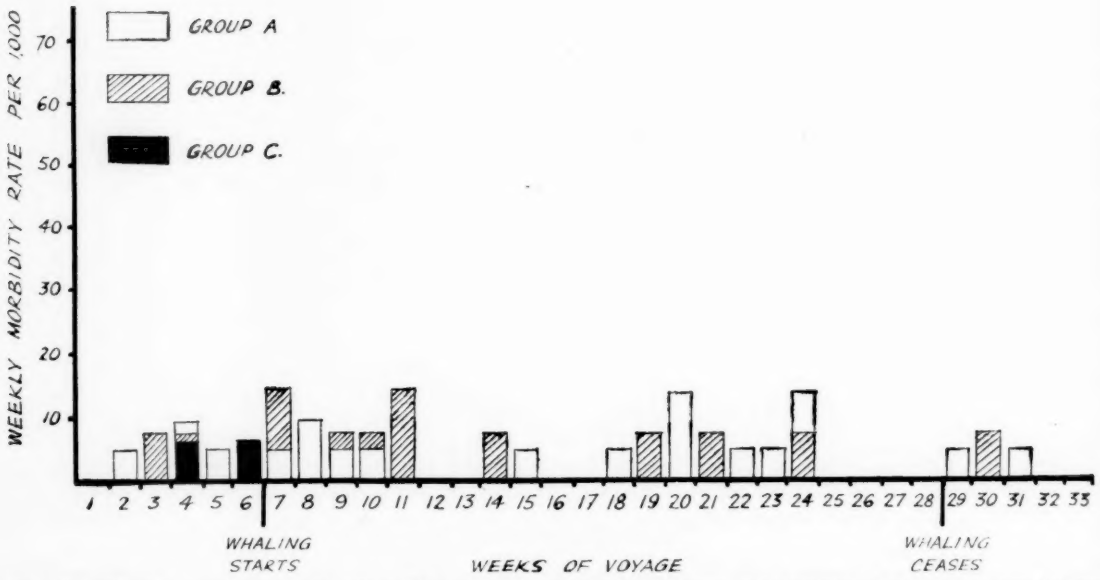

FIG. 9.—Weekly morbidity rate per 1,000 for each group for Column 9 (diseases of the upper respiratory tract).

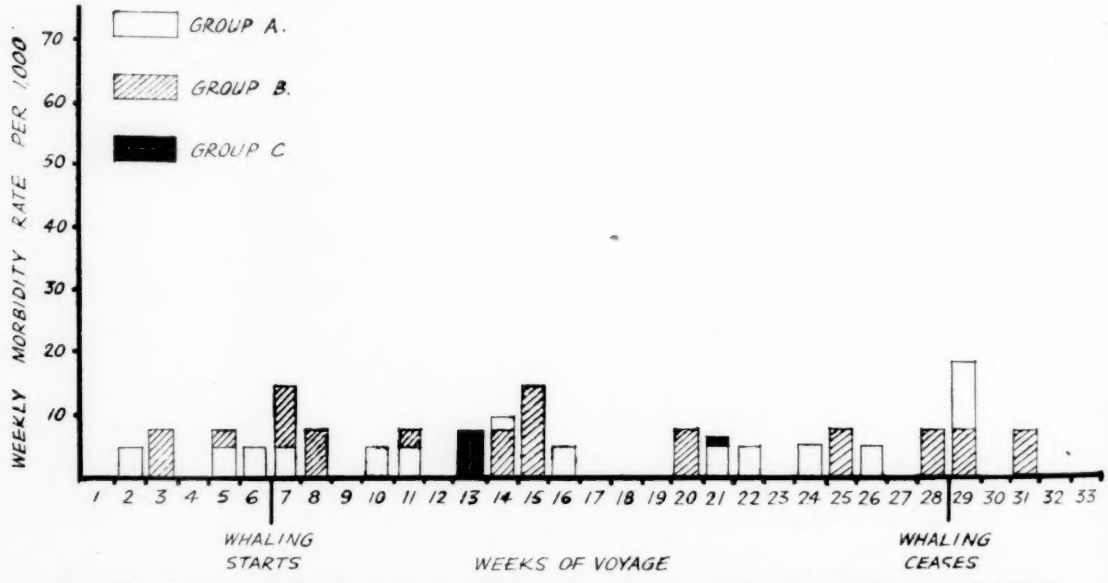

FIG. 10.—Weekly morbidity rate per 1,000 for each group for Column 10 (burns and scalds).

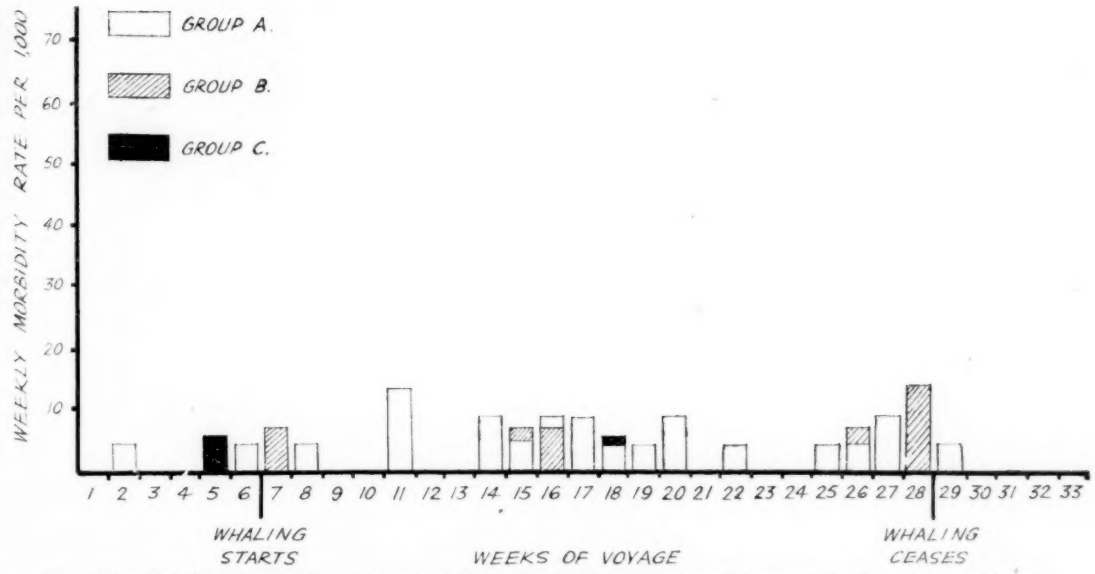

FIG. 11.—Weekly morbidity rate per 1,000 for each group for Column 11 (dental conditions).

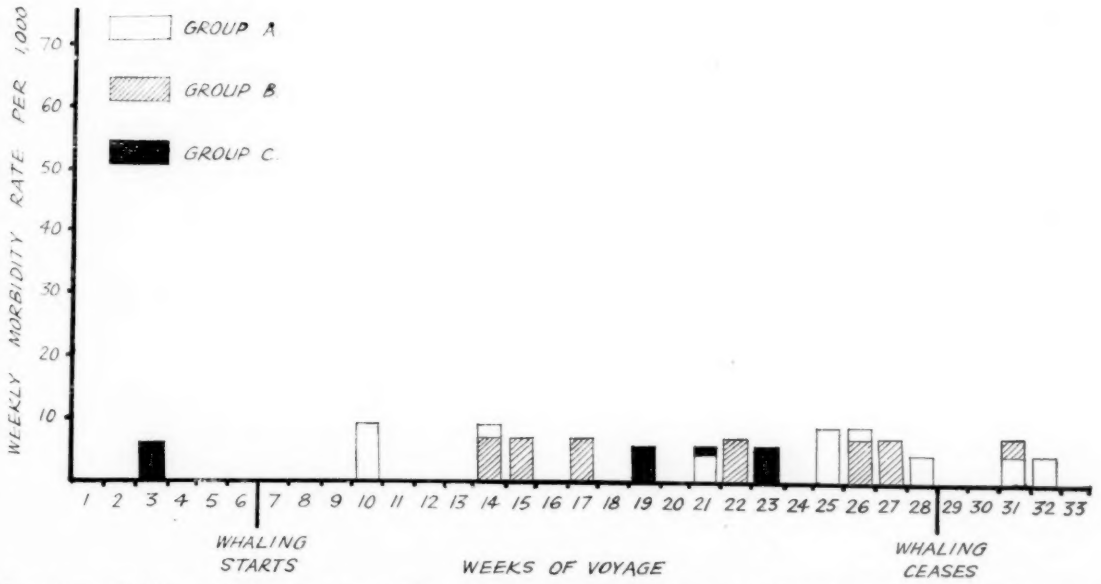

FIG. 12.—Weekly morbidity rate per 1,000 for each group for Column 12 (disorders of the central nervous system (organic and functional).)

FIG. 13.—Weekly morbidity rate per 1,000 for each group for Column 13 (diarrhoea).

computations because the difficulty of reporting for the more trivial ailments might bias the results.

The mean of the differences is taken as the fairest estimate because the values are all true paired values; all adventitious factors such as climatic conditions, the number of whales taken and their degree of decomposition will be exactly the same for each group. The parameters of significance are given.

DISCUSSION

During the voyage 933 reports of sickness were made (a total morbidity rate of 1,728 per thousand) and two deaths occurred (a mortality rate of 3·7 per thousand). Owing to the possibility of double entry previously mentioned, the total appearing in Table IV is 1,026. This will only bias the columns total morbidity and total classified morbidity, and these only to a small extent.

Tables IV and V are included mainly to provide the data on which the statistical operations were conducted, and to record this data for the convenience of future workers in this field.

Table VI shows that the whaling season has a significant influence upon the total weekly morbidity rate per thousand, and that this influence is most marked in group A. (Difference = +63·3, "t"= 4·0, P <0·001 for group A; difference = +9·7, "t"=0·8, P=0·4 for group B; difference= +26·7, "t"=2·9, P=0·007 for all three groups compounded.) These estimates might be slightly biased by the possibility of double entry.

When the columns are considered individually (ignoring column 14, Miscellaneous conditions, which is too heterogeneous a classification for analysis), there is seen to be an increased mean weekly morbidity rate per thousand in nine of the thirteen columns of group A during the whaling period. In five of these cases the increase is statistically significant if the value P=0·05 is

TABLE VII

THE INFLUENCE OF OCCUPATIONAL GROUP ON DISEASE: GROUPS A AND B

Column		1	2	3	4	5	6	7	8	9	10	11	12	13	Total
Transit	d	− 2·1	− 1·9	+3·5	−1·2	+0·2	−0·5	+1·9	+3·5	+0·9	+0·3	+1·2	+0·2	+1·6	+3·7
	t	1·0	0·7	0·9	0·6	0·1	0·4	1·0	1·7	0·8	0·2	1·9	0·4	2·3	0·4
	p	0·35	0·50	0·40	0·55	0·90	0·70	0·35	0·15	0·45	0·80	0·10	0·70	0·055	0·70
Whaling	d	+13·3	+10·5	+9·8	+4·7	+5·5	+2·4	+2·9	+1·3	−0·2	−1·3	+2·2	+0·1	+0·4	+53·3
	t	4·8	3·7	4·9	2·5	2·8	1·5	2·3	1·6	0·1	1·1	1·7	0·1	0·6	7·5
	P	<0·001	<0·001	0·001	0·02	0·019	0·15	0·035	0·13	0·90	0·27	0·10	0·90	0·55	<0·001

d = mean of differences of weekly morbidity rate per 1,000 of groups A and B.
A+ means a larger A value.

n transit = 11.
n whaling = 22.

accepted as the criterion of significance. In group B there is an increase in eight cases, but this increase does not attain statistically significant proportions.

Table VII shows that during the transit period group A had a higher morbidity rate than group B in nine columns, but this difference never assumed significant proportions, and only approached significance in one case. During the whaling period group A had a greater morbidity in all thirteen columns, and in six cases this difference was significant.

It may be fairly concluded from the above that whaling exerted a deleterious influence upon the health of the expedition's complement, and that this influence was felt almost entirely by the deck and factory workers, that is, by those actually handling the whale carcases. This influence was most marked in certain disease categories, viz. suppurative lesions; traumatic lesions without sepsis; non-diarrhoeic alimentary disorders; and dental conditions.

The increase in traumatic lesions might be expected as a consequence of the increased dangerous activity during the whaling period, and could be expected to contribute in some measure to the increase of sepsis, but the proportion of septic lesions to traumatic lesions without sepsis also rises.

The suppurative lesions may reasonably be assumed to have a relationship to the bacteriological findings discussed later, though no rigid establishment of causality by bacteriological methods was possible.

Some dried cultures from wounds were brought back on board *Balaena* and were examined after a lapse of about six to eight months, but only non-pathogenic clostridia and staphylococci were grown (Hobbs, 1947). However, a duplicate of a preparation that had previously shown *Cl. oedematiens* when flown back (Parish, 1947) was opened and examined at the same time as the preparations from septic wounds, and failed to reveal any pathogenic clostridia. It seems highly likely that some of the bacterial strains originally present were no longer viable after the time which had elapsed since drying. The drying was carried out on a vacuum pump, but no preliminary freezing technique was used.

Whether the increased incidence of alimentary disorders, "rheumatic" conditions, and dental disorders bear any relationship to the bacterial hazard or not is not shown.

The alimentary disorders were mainly a form of "gastritis" and this might have been produced partly by continuous reflex stimulation due to the gases from decomposing protein. It seems to be generally supposed that the smell of a whale-factory is due to the boiling of fatty material. In fact it seems very largely due to the anaerobic bacterial decomposition of hundreds of tons of meat (one whale may weigh over one hundred tons, of which approximately 70 per cent. is said to be muscle, and the flesh of three whales may easily be on deck at one time), and is present continuously. The smell is certainly extremely nauseating, and very little olfactory fatigue sets in.

The sepsis occurring was of great interest. In the two instances of death, post-mortem examinations were conducted, and extracts from the reports of these are given below.

Case 1

The victim, a plan foreman, was struck on the head by a hook when a cable parted. Death occurred two days later.

"Death was due to acute meningitis and cerebral oedema following a fracture of the skull due to direct violence. A contributory factor was bronchopneumonia. Whilst it is impossible to say whether the trauma alone would have proved fatal, there can be little doubt that the chances of survival were seriously jeopardized by the spread of infection to the meninges. The bacterial flora found was similar to that recovered from the muscle of 'burned' (decomposed) whale." (Sporing Gram-positive bacilli, Gram-negative bacilli, and streptococci.)

The whale that was being handled at the time was a very decomposed fender whale, and the whole of the musculature was reduced to a greyish putty-like mass by putrefaction.

Case 2

A deck hand who ran a steel hook into his calf died under anaesthesia during an operation for amputation of the leg for gas gangrene. This operation was started forty-eight hours after the accident. Penicillin and sulphonamide had been given. Clinically the case was a typical one of fulminating gas gangrene.

"The appearances are those of an acute toxaemia from fulminating gas gangrene. Though it is impossible to exclude the anaesthetic as a factor in accelerating death, the amount of thrombus in the heart indicates that the patient was in fact moribund at the time the operation was commenced. The source of the infection was the wound of the right leg."

Bacteriological examination revealed the presence of a sporing Gram-positive bacillus only.

Thus in one of these cases death was indisputably due to gas gangrene, and sepsis that could have originated in whale muscle cannot be excluded as a factor causing death in the other.

Many other cases were very resistant to treatment, and some were clinically gas-forming infections.

During the flensing and subsequent operations it is very common for the workers to acquire small cuts on their hands, or to pierce their hands or legs with hooks or wires. The danger from these

wounds is well recognized in whaling lore, the resultant intractable and often crippling sepsis being spoken of generally as " blubber-finger." It is said that the incidence and severity of this condition varies from year to year and even from region to region in the same year. Tales are told of ships losing many men in a season from this complaint, but little medical investigation of the condition seems to have been undertaken.

It is also said that a " sick whale " is particularly likely to cause such trouble, but it was impossible to find out exactly what a " sick whale " is.

Some bacteriological studies had been carried out on board *Balaena* during the season (Case, 1947), and it had been established that, quite soon after the death of the whale, the musculature became heavily contaminated with a mixed bacterial flora derived presumably from the intestinal tract. This flora consisted typically of sporing and non-sporing Gram-positive bacilli, proteolytic, saccharolytic, and sometimes both; Gram-negative bacilli; and faecal-type streptococci. Occasionally, but not typically, *Staphylococcus albus* was found. The bacterial contamination became progressively more massive as the time from death increased.

It was also established that the temperature of the whale *in vivo* was about 35° C., and that this temperature was maintained to within a degree even in a whale that had been left in the sea for five or six days after death. It was therefore not surprising to find that rapid invasion of the musculature took place.

Dried cultures of bacteria grown from whale muscle had been sent back to this country by air, and, amongst a mixed flora of clostridia, *Cl. oedematiens* (Parish, 1947) and *Cl. chauvoei* (Shrewsbury, 1947) were identified.

Swabs were taken from a series of cases of sepsis, and cultured in peptone water and cooked-meat medium. Direct smears were also examined. The findings are shown in Table VIII.

It is seen that the three main types of bacteria found in decomposing whale muscle and in the contents of the whale's intestine appeared frequently in these wounds. The most notable exception was

TABLE VIII

BACTERIOLOGICAL FINDINGS IN FIFTEEN CASES OF SEPSIS (DIRECT FILM AND CULTURE)

Period	Group	Nature of wound	G+ve B	G—ve B	Strep	Staph
W	A	Suppurative otitis media	+	+	+	+
W	A	Septic laceration of hand	+	+	+	+
W	A	Fatal puncture wound of leg	+	—	—	—
W	A	Fatal wound of head	+	+	+	—
W	A	Septic laceration of hand	+	—	+	—
W	A	Septic traumatic amputation of finger ..	+	—	—	—
W	A	Septic finger	+	+	+	+
W	A	Urethral smear (non-specific urethritis) ..	+	+	—	+
W	A	Septic finger	+	—	—	+
W	B	Septic laceration of hand	+	+	+	—
W	B	Septic laceration of hand	+	+	+	+
W	B	Septic finger	+	+	+	—
W	C	Septic finger	—	—	—	+
W	C	Septic laceration of hand	—	—	—	+
W	C	Septic laceration of hand	—	—	—	+

G+ve B = Gram-positive bacillus.
G—ve B = Gram-negative.
Strep = Streptococcus.
Staph = Staphylococcus.

in the three cases of catchers' crew patients, where staphylococcus only was found. All the other cases showed Gram-positive bacilli. In some of the cases these were probably saprophytic, in others they were probably pathogenic, and in one case the cause of death.

The heavy bacterial contamination of much of the material handled by the deck workers, under conditions where wounds are common, presents an obvious hazard; and it is suggested that the increased sepsis rate amongst deck workers is probably caused by this contamination. In view of the actual occurrence of gas-forming infections, the findings of pathogenic clostridia of the gas-gangrene group in cultures from whale-muscle, and the reports of high mortality rates in some years from what sounds like a type of gas gangrene, it is felt that the risk of clostridial infection as a hazard of whaling should be borne in mind by the ships' medical officers, and that appropriate hospital stores should be carried.

The risk of sepsis might be mitigated to some extent by keeping the period between the death of the whale and processing as short as possible, and by refraining from flensing decomposed fender whales, or, as sometimes happens, whales that are found drifting about dead and decomposed. These whales are presumably " flagged " whales that have been lost. Cleansing of the decks and cleaning of hooks in antiseptics might also prove desirable.

The possibility of seasonal and regional variations of the predominating bacterial flora, which is presumably derived from the Euphausids and squids on which the baleen and toothed whales respectively feed, should be considered. It would seem highly desirable for further bacteriological studies of sepsis to be carried out.

The possible implications of bacterial contamination of whale meat intended for human consumption are, and have been for some time, under consideration by competent authorities in this country, and none of the findings reported in this paper should be interpreted as suggesting that such meat as is taken for human consumption is necessarily in any way unfit or suspect.

Summary

The hospital data accumulated on a whaling expedition to the Antarctic pelagic whaling grounds is analysed and discussed, and it is shown that the whaling season exercises a deleterious influence on the health of the crew of the factory ship.

This influence is felt in the main by the deck workers and factory workers, and the largest increase of disease occurs in the diseases classified as suppurative lesions, traumatic lesions without sepsis, non-diarrhoeic alimentary disorders, " rheumatic " conditions, and dental disorders.

The sepsis, which in this cruise caused one death and was at least a contributory factor in the second, was often associated with the typical bacterial flora of the whale's intestine, which soon after death causes heavy bacterial contamination of the whale muscle. It is suggested that gas gangrene should be thought of as a real danger to whalers, and that the hospital stores and equipment should be organized accordingly.

The figures are given in detail, in order to form a body of data for reference for other workers in this field.

It is suggested that every endeavour should be made to keep down the time elapsing between killing and processing the whale, and that the practice of flensing fender whales after they have become decomposed is very undesirable from a hygienic point of view.

My thanks are due to Dr. Jamis Hutchison, Medical Officer on board Fl. F. *Balaena* 1946-7, for all the co-operation he gave in making it possible to complete these studies, to Mr. Kenneth Whittle of the Royal Isle of Wight County Hospital, and to Mr. Alexander Ireland, of the Infirmary for Sick Children, Glasgow, for their invaluable help in the laboratory investigations on board.

My thanks are also due to Professor J. D. Shrewsbury, the University of Birmingham, Dr. Betty Hobbs, Central Public Health Laboratory, and Dr. H. J. Parish, of Messrs. Burroughs Wellcome Ltd., for examining bacteriological material brought back, and, in the case of Dr. Parish, for advising upon and obtaining prophylactic and therapeutic sera for the next expedition. United Whalers Ltd. have carried out part of the recommendations outlined above.

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ARMY EXPERIENCE OF SYPHILIS THERAPY

BY

C. C. M. JAMES, DONALD G. MACKAY, and J. T. WRIGHT

1. Introduction

The prevention of syphilis is a major problem of social medicine; and its prevention is closely interlocked with the efficacy of treatments available. For this reason it is surely appropriate in this context to examine new sources of information with respect to its therapeutic control as a pre-requisite to consideration of other methods of eliminating the disease. Experience of syphilis therapy in the Army during the late war provides unique materials for assessing therapies in current use, and it is the aim of this communication to assess their value.

During the first phase of the war, Army medicine relied exclusively on long-term arsenotherapy with bismuth. Later a certain number of cases was treated by means of short-term mapharside with bismuth. In the last phase penicillin treatment replaced or supplemented the use of arsenicals for a trial period pending the outcome of experience. In all, we are in a position to examine the results of eight procedures which we specify more fully below (part 5):

1. 2·4 mega units of penicillin.
2. 4·0 mega units of penicillin.
3. 2·4 mega units of penicillin + 0·6 g. mapharside.
4. 2·4 mega units of penicillin + 0·4 g. mapharside + 1·0 g. bismuth.
5. Long-term arsenic therapy, high aggregate dosage.
6. Long-term arsenic therapy, low aggregate dosage.
7. Long-term arsenic therapy + 2·4 mega units of penicillin.
8. Short-term arsenic therapy.

2. Sources of Material

Long-term arsenic cases were traced through the War Office Central Card Index which supplied a nominal roll of all syphilis cases admitted to hospital for treatment during the twelve months 1943-4. The same nominal roll also served for a survey of post-arsphenamine jaundice (Truelove and Hogben, 1947). Nominal rolls obtained from the Adviser in Venereology made it possible to trace cases undergoing initial treatment (by methods later specified) at Army Special Treatment Centres in Britain during the period September, 1944, to June, 1946. During this period each Special Treatment Centre (S.T.C.) was treating all cases of *early* syphilis with a standard schedule of therapy notwithstanding the duration or severity of the disease. Hence such nominal rolls should provide an unbiased sample of the total Army early syphilitic population at home. By recourse to the serial numbers supplied by them, it was possible to extract hospital record cards (A.Fs. I.1220) from the Central File of Medical Documents at the War Office and from the Central Syphilis Register (C.S.R.). The former furnished detailed information with reference to *initial* syphilitic infection and treatment. The latter supplied surveillance notes relating to each case.

Many cases on the nominal rolls from S.T.Cs. were unserviceable for the following reasons:

(1) patients from other Services, initially treated in military units were subsequently transferred from Army supervision;
(2) some patients had had previous treatment for the disease;
(3) some cases were congenital, tertiary, neurosyphilitics, or latent syphilitics;
(4) relevant documents of a small group were incomplete:

All cases under consideration are *early*. They had neither suffered previously from the disease nor undergone previous treatment, but otherwise include any diagnosed as sero-negative primary syphilis, sero-positive primary syphilis, and early secondary syphilis. The diagnostic criterion of *primary* cases was presence of a primary chancre confirmed by detection of *Treponema pallidum* by dark-ground examination, with or without positive serological test (Wassermann or Kahn). That of secondary syphilis was a positive Wassermann or Kahn test together with such clinical manifestations as a rash, mucous patches, or condylomata (confirmed as such by dark-ground examination).

3. Criteria of Efficacious Treatment

Inter alia we may judge the therapeutic efficacy of a drug in terms of the risk of relapse, or the frequency of beneficial response whether temporary or otherwise. Accordingly, we here distinguish two categories of cases as *relapses* and *failures*, the former among whom the benefit of treatment is only temporary, the latter because they fail to derive any manifest benefit at all. Any index which combines figures referable to both criteria is necessarily arbitrary, because we have no reason to

suppose that a treatment which is accredited by a lower *relapse* rate will be accredited by a lower *failure* rate; and if the two methods of assessment point to different conclusions, no formula applicable to all diseases prescribes which should have priority. Since we cannot compute relapse rates without excluding cases which at no time responded to treatment, we have thus to apply to our data two independent criteria of efficacy: (*a*) what proportion of all cases treated *fail* to respond at any time; (*b*) among cases which do respond at some time, what proportion subsequently relapse.

Considerations which did in fact guide our classification of cases as failures, relapses, or cures, call for more explicit clarification. Both for diagnosis and for surveillance, treatment centres concerned in the present investigation employed the qualitative Wassermann reaction (W.R.), the qualitative Kahn test (K) and quantitative Kahn test (K.Q.). Owing to exigencies of the Service, the W.R. and Kahn were not always used together in surveillance; but quantitative Kahn tests (K.Q.) performed in the majority of cases give evidence of serological trends. We here consider a serum to be *positive* when the laboratory reported any one of the following: W.R.+, K+, or K.Q. of four or more units. We classify as *doubtful* a result such as K±, W.R.±, or K.Q. readings of less than four units. Blood samples from each case were commonly examined both at beginning and end of treatment. The routine of surveillance entailed clinical and serological examination at 2, 4, 6, 9, 12, 15, 18, and 24 months after completion of treatment. Lumbar puncture was performed at 6, 18, and 24 months.

We here regard a case as *cured*, if it conforms to each of two criteria: (*a*) all lesions have healed at the conclusion of treatment; (*b*) the serological test is negative at the end of surveillance. We also regard as a cure, any case ending surveillance prematurely with one sero-negative test (e.g. W.R.) and one doubtful (e.g. Kahn) if it satisfies each of the following criteria: (*a*) there has been consistent decline from an originally high titre; (*b*) there are no remaining clinical signs of syphilis. Clinical records (A.Fs. I.1220) provide the information on which we rely for specification of *relapse* in accordance with either of the two criteria on which we base the initial diagnosis, viz. (*a*) presence of fresh clinical manifestations in which *Treponema pallidum* could be demonstrated; (*b*) positive serological test, if previous tests had been negative or of lower titre. Reappearance of muco-cutaneous lesions in which *Treponema pallidum* is demonstrable provides clear-cut evidence of relapse; but the serological criterion is not, of itself, unequivocal.

Many cases lost in the follow-up (*defaulters*) were not sero-negative at the time. They were either sero-positive or serologically doubtful; and their previous serology may have been: (i) positive with a steady or rising titre; (ii) positive with a declining titre; (iii) consistently or at some time negative. Cases we classify as *failures*, in contradistinction to relapses, are cases which did not become sero-negative within four months of the end of treatment but continued with a high titre or an increasing titre until they were lost to surveillance. In this context failure therefore means inefficacy of a treatment to reverse or to reduce the serological titre by the fourth month. There were few among the long-term arsenic series, and only among such as received small aggregate doses of arsenic owing to supervening dermatitis or jaundice. In the penicillin and short-term arsenic series some failures renewed treatment as soon as there was clear evidence of defective response. The rest would almost certainly have been re-treated, had they not defaulted.

Cases defaulting from surveillance with a titre still positive but steadily declining from an initially high level are obviously *doubtful*. Cases with a positive serum after one or more clear-cut negative tests during surveillance are by definition relapses at the month in which they become positive. Others classified as *doubtful* had a doubtful serum reaction at their last surveillance before they defaulted, because further surveillance might have demonstrated a steadily rising titre or fresh muco-cutaneous lesions indicative of relapse. In a very few instances, a weakly positive serum reaction interrupted an otherwise consistently negative surveillance. The subsequent negative clinical and serological trend, confirmed by absence of abnormality in the cerebro-spinal fluid, suggested that such isolated positive

TABLE I

PERCENTAGE OF CASES ENDING WITH AN EQUIVOCAL SEROLOGY REJECTED FROM THE SERIES ON ACCOUNT OF FOLLOW-UP OF LESS THAN FOUR MONTHS

	Primary Sero-positive		Secondary	
	Total cases	% cases rejected	Total cases	% cases rejected
Pen. 2·4	163	0·0	119	0·8
Pen. 4·0	44	6·8	30	6·7
Pen. and Maph.	113	2·7	59	10·2
Pen. and Maph. +Bismuth ..	92	3·3	56	14·3
LTA. and Pen. ..	38	0·0	26	0·0
LTA. (A) ..	84	0·0	67	0·0
LTA. (B) ..	84	0·0	47	2·1
STA.	38	0·0	42	0·0

reactions were either of the falsely positive type or were due to laboratory errors. Little can be predicted of a case which defaults from surveillance at the second or third month with a serum still positive or doubtful and without any stigmata of clinical relapse. Since the time under surveillance is quite inadequate to disclose the ultimate trend, we have rejected them from our pool of data. Table I shows the percentage of all cases available for follow-up in each series and those rejected for reasons here stated.

In therapeutic trials involving a communicable disease a common difficulty arises in connexion with delimitation of relapses and re-infections. Eighty-five cases in all treatment groups of our series were known to develop additional syphilitic lesions. The venereologist's opinion as stated in the clinical records distributes the later lesions as follows:

Relapses	.. ..	33
Reinfections	.. ..	12
Inconclusive	.. ..	40

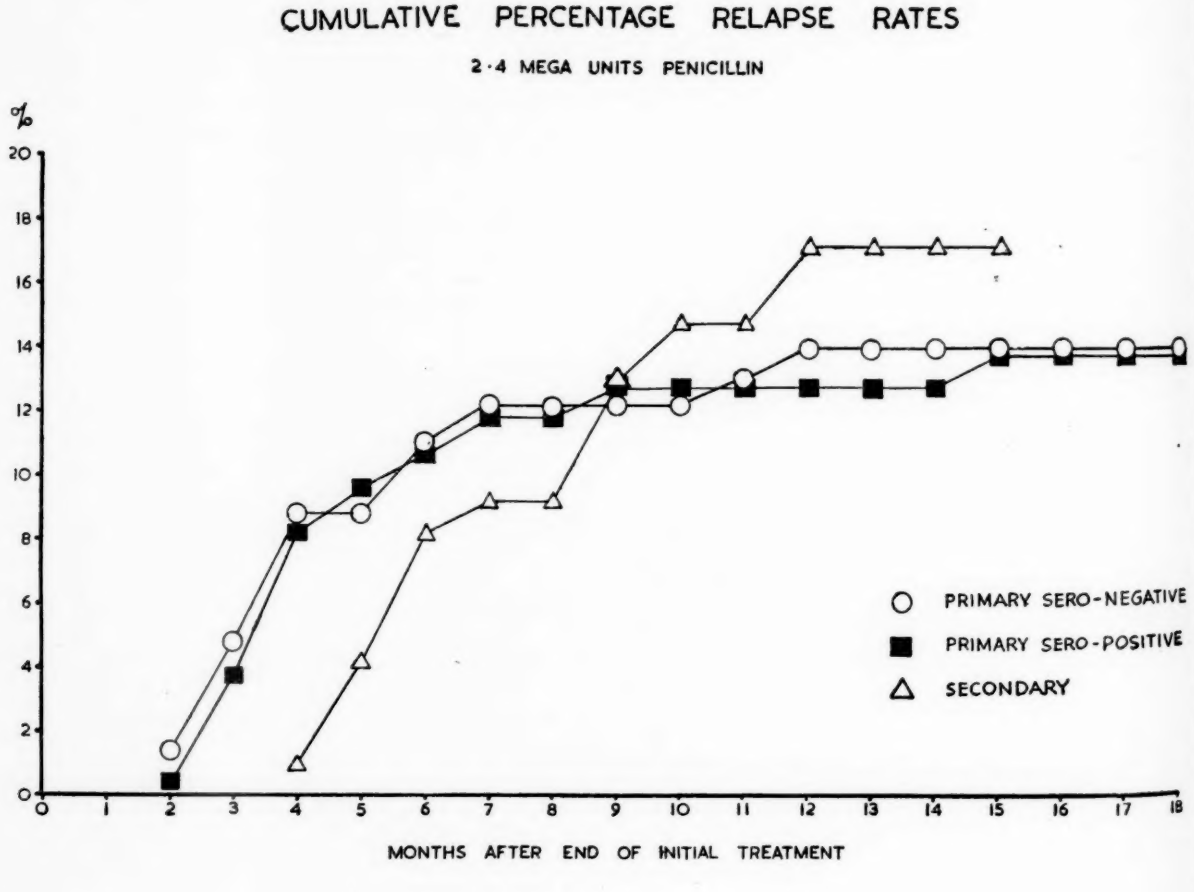
It has hitherto been customary (Moore, 1943) to exclude a diagnosis of reinfection unless consonant with all of the three following criteria:

(i) " There must be proof that the patient had syphilis prior to the occurrence of the suspected second infection, and this proof must rest on the demonstration of spirochaetes in a lesion or the occurrence of a positive blood Wassermann reaction in the blood serum, and not on clinical judgment alone."

(ii) " After an interval following antisyphilitic treatment and at a site other than that of the primary lesion of the first infection, there must develop a lesion with the characteristics of a chancre in which spirochaetes can be demonstrated."

(iii) " That at the time of the supposed second infection the serologic test is negative; and that while under observation and during a period in which treatment is purposely withheld, the serologic test becomes positive or the patient develops outspoken secondary syphilis."

The clinical records of our cases do not indicate that the venereologist's opinion relied on the



coincidence of these three criteria. The first of Moore's criteria (i) was indeed fulfilled in all our cases; but analysis of the sample on the basis of the other two yielded the figures given in Table II.

TABLE II

	Sore at original site		Sore at new site		Total
	Sero-pos.	Sero-neg.	Sero-pos.	Sero-neg.	
Cited as relapse	28	3	2	0	33
Cited as reinfection	3	2	6	1	12
Non-committal	26	7	3	4	40
Total	57	12	11	5	85

Records usually laid emphasis on a history of recent exposure where citing a diagnosis of reinfection. It is reasonable to assume that the 57 cases whose second lesions appeared at the site of the original chancre with coincident positive serum reaction were definite cases of muco-cutaneous relapse. Probably, the 12 cases which were sero-negative when a second lesion appeared on the original sites were also muco-cutaneous relapses. *Inter alia*, Rabut and Hudelo (1924) described 21 such cases in a series of 51. Muco-cutaneous relapse in the presence of a negative or doubtful serum is thus well accredited. The 11 cases whose second lesions were stated to have occurred at different sites from the original chancres at a time when the serum was positive are more difficult to assess. It was clear from the notes of some that the new lesions were sufficiently close to be within the lymphatic watershed of the original site, a fact which might well suggest that they were probably muco-cutaneous phenomena. On the other hand, records of one or two with typical chancres proved to contain *Treponema pallidum* at a site well away from the original chancre and associated with enlargement of lymph glands other than those stated to be enlarged in the original infection, cite a doubtful serum reaction. It is conceivable that such cases were, in fact, reinfections. Of the five remaining cases, none fully satisfies the criteria advanced by Moore. We therefore regard them as relapses, and cite further details with reference to them in Table III.

The evidence that the second sore differed significantly in respect of site from the initial chancre is poor in cases 1, 2, and 4. In case 3, the new lesion was apparently still within the lymphatic watershed of the initial chancre. Case 5 is the only one in which a negative serum reaction in the presence of the second sore was observed to have become positive before further treatment was instituted. Unfortunately, dark-ground examination was not done until the sore had been present for one month. It was then negative on three occasions. In no case was there evidence that "repeat" blood tests had been used to confirm routine tests.

4. Calculation of Relapse Rates

All time periods date from the end of the course of treatment. In what follows, the assumption is that we have sorted our data to exhibit:

(*a*) numbers of sero-negative individuals (x_{m-1}) still under observation at the beginning of the *m*th month from date of certification;

(*b*) ditto (x_m) still remaining under observation at the end of the *m*th month;

(*c*) relapses (y_m) during the *m*th month;

(*d*) defaulters (d_m), that is, individuals who have ceased to be under observation during the *m*th month.

The last item is evidently deducible from the others by the relation:

$$d_m = x_{m-1} - x_m - y_m \quad \ldots\ldots\ldots\ldots\ldots\ldots (i)$$

Our problem is to ascertain the chance of relapse during the *m*th month, denoted below as q_m. If there were no defaulters, this would be the ratio of relapses during the month to sero-negative individuals at the beginning, that is, $y_m \div x_{m-1}$; but d_m defaulters would have accounted for an unascertained number (e_m) of relapses during the same period, so that the correct value is given by:

$$q_m = \frac{y_m + e_m}{x_{m-1}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (ii)$$

Our problem is therefore to estimate e_m. Let us suppose that all the d_m individuals had ceased to be available for further observation on the first day of the *m*th month after reporting for the census recording x_{m-1} sero-negative individuals at that date. If so, e_m would be the relapses during the month referable to an initial population of d_m sero-negative individuals, i.e.

$$q_m = \frac{e_m}{d_m} \text{ or } e_m = q_m\, d_m$$

In fact, we are entitled to assume that the stream of defaulters is steady, the mean time during which they were available for observation being $\frac{1}{2}$ a month. We may therefore put approximately

$$e_m = \tfrac{1}{2}\, q_m\, d_m$$

TABLE III

Case	Age	Site of first sore	Sites of adeno-pathy	Initial serology	Treatment	Serology after treatment to time of development of 2nd sore	Time of appearance of 2nd sore after treatment of 1st	History of new exposure to infection	Site of 2nd sore	Sites of adeno-pathy	Serology at time of development of 2nd sore	Venereologist's diagnosis
1	42	Left side of glans and sulcus DG Tp +	Inguinal bilateral	(W.R. not done) Kahn negative	Pen. 2·4 mega units	Negative at second month	Third month	3/52 E.M.C. 6 days marital	The meatus Tp +	Inguinal bilateral	(W.R. not done) Kahn negative	"Syphilis early"
2	29	Coronal sulcus DG Tp +	Inguinal bilateral	W.R. and Kahn negative	Pen. 2·4 mega units	Consistently negative	Eighteenth month	2/12 E.M.C. 3 days marital	Coronal sulcus DG Tp + (not on original site)	Inguinal left	(W.R. not done) Kahn negative	"Syphilis early"
3	20	Prepuce and glans DG Tp +	Inguinal bilateral	W.R. and Kahn negative	Pen. 2·4 mega units + maph. 0·6 g.	Consistently negative	Sixth month	6/52 prostitute	Papule in rt. inguinal region DG Tp + penis clear	No adeno-pathy	(W.R. not done) Kahn negative	"Syphilis primary"
4	33	Fraenum DG Tp +	Inguinal bilateral	(W.R. not done) Kahn positive	Pen. 2·4 mega units	Negative at 2nd month	Third month	Not stated	Prepuce DG Tp +	Inguinal bilateral	(W.R. not done) Kahn negative	"Reinfection"
5	25	Ventral surface of shaft of penis DG Tp +	Inguinal left	(W.R. not done) Kahn doubtfully positive	Mapharside and bismuth (S.T.A.)	Consistently negative	Seventeenth month	2/12 E.M.C.	Dorsum of penis DG Tp neg. 1/12 after sore appeared	Not stated	Kahn neg. when sore appeared. Became positive before retreatment	"Syphilis early"

(E.M.C. = extra-marital coitus.)

It is worthwhile to point out that there is only one arbitrary assumption in the above relation, that is to say, a linear rate of default in the interval. Otherwise the relation is exact for the following reason. Suppose that we divide the month into a large number (s) of intervals in each of which the number of defaulters is $d_m \div s$. At the beginning of each interval the number of defaulters is thus the same; but their contributions to the total (e_m) of unidentified relapses will be different. The first batch with a month before them can contribute to this total $q_m\, d_m \div s$. The second batch with a residual fraction of a month equivalent to $(s\text{-}1) \div s$ can contribute only $\overline{s\text{-}1}\, q_m\, d_m \div s^2$, and so on. The best estimate of e_m is the limiting value of the corresponding sum of the contributions of the batches when s is indefinitely large, that is:

$$e_m = \mathrm{Lt}\ \frac{q_m\, d_m}{s^2}\left\{s + \overline{s\text{-}1} + \overline{s\text{-}2} \ldots\ldots 2 + 1\right\}$$

$$\therefore\ e_m = \tfrac{1}{2}\, q_m\, d_m.$$

Hence by (i) above

$$e_m = \tfrac{1}{2}\,(x_{m-1} - x_m - y_m)\ .\ q_m \qquad \ldots\ldots (iii)$$

Likewise by (ii) above

$$q_m = \frac{y_m + \tfrac{1}{2} q_m\,(x_{m-1} - x_m - y_m)}{x_{m-1}} \qquad \ldots\ldots\ldots (iv)$$

$$\therefore\ 2\, q_m\ .\ x_{m-1} = 2y_m + q_m\, x_{m-1} - q_m\, x_m - q_m\, y_m$$

$$\therefore\ q_m\,(x_{m-1} + x_m + y_m) = 2y_m$$

$$\therefore\ q_m = \frac{2y_m}{x_{m-1} + z_m + y_m} \qquad \ldots\ldots\ldots\ldots (v)$$

The appropriate computing scheme for the estimation of q_m is thus:

Date by month (1st day of)	*Residual sero-negative population*	*Serological relapses*	*Defaulters from equation (i)*	q_m *from (v)*
0	x_0			
.....		y_1	d_1	q_1
1	x_1			
.....		y_2	d_2	q_2
2	x_2			
.....		y_3	d_3	q_3
3	x_3			

Corresponding to q_m the relapse rate, the survival rate s_m showing the chance of remaining negative throughout the month m is given by:

$$s_m = 1 - q_m$$

The chance of remaining sero-negative to the end of the mth month from the beginning of the follow-up is the combined product

$$\prod_{1}^{m} s_r$$

With a computing machine the effort involved in extracting the continued product is small; but it is not a necessary operation and the two methods of arriving at a result should be the same. The second is to proceed thus:

Residual sero-negatives	*Observed relapses*	*Estimated relapses*	*Cumulative estimated relapses*
x_0			
	y_1	$y_1 + e_1$	$y_1 + e_1$
x_1			
	y_2	$y_2 + e_2$	$\sum_{1}^{2} (y_r + e_r)$
x_2			

Thus the cumulative relapse rate during m months as a percentage is:

$$100 \sum_{1}^{m} (y_r + e_r) \div x_0$$

This should be equal to:

$$100 \left\{ 1 - \prod_{1}^{m} (1 - q_r) \right\}$$

in which $(1 - q_r) = s_r$ of the preceding development.

5. Particulars of Treatments

Cases which received penicillin fall into the following groups:

1. *2·4 mega units* of sodium penicillin by three-hourly intramuscular injections of 40,000 Oxford units over a period of $7\frac{1}{2}$ days with no treatment other than local applications of saline or occasionally Eusol and other antiseptics to lesions;

2. *4·0 mega units* of sodium penicillin given as above but for 12½ days;

3. *2·4 mega units* of sodium penicillin in 7½ days with a course of intensive arsenotherapy beginning on the second day of penicillin treatment, viz. *mapharside 0·06 g.* intravenously daily for a period of 10 days;

4. *2·4 mega units of penicillin, 0·4 g. mapharside, and 1·0 g. bismuth* given concurrently as above (3) over a period of 10 days.

Standard commercial preparations were used. The proportions of the different crystalline penicillins in these preparations are not known.

"*Long-term*" *arsenic cases* call for more detailed specification. Ostensibly, it was the policy to treat all cases of: (*a*) primary syphilis with at least four courses of arsenic and bismuth given concurrently in a twelve-month period, each course consisting of 5·85 g. of N.A.B. and 2·0 g. of bismuth; (*b*) secondary syphilis with at least five courses of arsenic and bismuth. In practice, it rarely proved possible to implement this procedure consistently. In fact, cases in our series treated with apparent success received from between 3 to 27 g. N.A.B. and 3 to 18 g. of bismuth over periods varying from 8 to 23 months. Documentation with respect to some cases was poor, only the number of courses being stated. Other long-term cases received, in addition to N.A.B. and bismuth, two weekly injections of 0·06 g. mapharside in place of a single injection of 0·6 g. N.A.B. Cases receiving mercurials (3 per cent. of all) were rejected from the pool of data. The composition of the group was as follows:

		% (437 cases)
N.A.B. Bi.	No. of courses and dosage known ..	61
N.A.B. Bi. mapharside	No. of courses and dosage known ..	16·6
N.A.B. Bi. mapharside	No. of courses known. Dosage not stated	22·4
		100·0

Cases which received mapharside and cases for which treatment dosage was not fully stated make up more than a third of the total material available. So it was decided to retain them. In specifying the equivalent dosage of N.A.B. received by such cases, we equate 0·12 g. of mapharside to 0·6 g. N.A.B. and add the quantity of N.A.B. so computed to the actual amount of N.A.B. received.

TABLE IV

MEAN VALUE IN GRAMMES FOR N.A.B. AND BISMUTH AND MEAN VALUE IN MONTHS FOR PERIOD OF TREATMENT IN CASES RECEIVING FOUR COURSES OF N.A.B. AND BISMUTH

Diagnosis	No. of cases	Mean dose N.A.B. (g.)	Mean dose bismuth (g.)	Mean duration of treatment (months)
Primary: sero-negative	36	19·5 ±0·6	9·3 ±1·3	13·2 ±0·5
Primary: sero-positive	66	19·0 ±0·5	9·5 ±0·4	13·7 ±0·6
Secondary	38	19·0 ±0·2	9·7 ±0·5	14·1 ±0·5

From analysis (Table IV) of dosage given in four courses to cases with reference to which the information was available, it was possible to distribute the L.T.A. cases among two groups: (i) group A cases receiving more than 19·0 g. of N.A.B. or, where

TABLE VA

ANALYSIS OF CASES RECEIVING MORE THAN 19·0 g. N.A.B. PLUS BISMUTH

Diagnosis	No. of cases	Mean dose N.A.B. (g.)	Mean dose bismuth (g.)	Mean duration of treatment (months)
Primary: sero-negative	28	22·1 ±0·9	9·5 ±0·6	14·1 ±0·9
Primary: sero-positive	50	22·1 ±0·4	9·7 ±0·2	13·7 ±0·4
Secondary	52	22·3 ±0·3	10·2 ±0·4	14·7 ±0·4

TABLE VB

ANALYSIS OF CASES RECEIVING LESS THAN 19·0 g. N.A.B. PLUS BISMUTH

Diagnosis	No. of cases	Mean dose N.A.B. (g.)	Mean dose bismuth (g.)	Mean duration of treatment (months)
Primary: sero-negative	75	13·0 ±0·5	8·7 ±0·2	12·2 ±0·4
Primary: sero-positive	81	14·4 ±0·3	9·8 ±0·2	14·1 ±0·4
Secondary	53	13·4 ±0·6	9·5 ±0·4	14·0 ±0·4

dosage was not stated, four or more courses of arsenic and bismuth; (ii) group B cases receiving either less than 19·0 g. of arsenic or less than four courses of arsenic and bismuth. Tables VA and VB show that the only obviously significant difference between these groups is the dosage of arsenic.

As a result of this analysis, 79 cases receiving between four and six courses of arsenic and bismuth were added to group A, whilst 19 cases receiving between two and three courses only were added to group B. No significant departures from these mean values occurred among cases which were known to have relapsed in the two groups. Analysis of group A and B cases with reference to the incidence of jaundice revealed a highly significant difference (Table VI) between the two groups. This was, of course, the prime reason for the lower average arsenic dose in group B. The incidence of dermatitis was also higher in this group, though it was a minor contributory factor in lowering the arsenic dosage for the group. Differences with reference to incidence of jaundice between the three subdivisions within each group are not statistically significant, though examination of a larger series of cases has shown that maximum susceptibility to jaundice occurs during the very early stage of syphilis.

A group of "long-term" arsenic cases subsequently treated with penicillin started treatment on a purely "long-term" arsenic basis, but after a variable interval arsenotherapy was stopped; and they were given a routine course of penicillin, 2·4 mega units in 7½ days. Table VII shows the mean values for arsenic and bismuth received prior to penicillin therapy, and the mean period over which therapy (including penicillin) took place.

It can be seen that similar amounts of N.A.B. and bismuth were given throughout and that the period between the beginning of arsenotherapy and the end of penicillin injections was not unduly variable. Amongst cases which are known to have relapsed there were no significant departures from the mean values given above. The three divisions into primary sero-negative, primary sero-positive, and secondary cases refers to the condition at the inception of arsenotherapy. By the time penicillin therapy began, most of the initially sero-positive cases had become sero-negative. Table VIII indicates the proportion of cases in which sero-reversal had taken place, those in which the serum test was still positive, and those who had not had a recent test.

TABLE VI
% JAUNDICED

	No. of cases	Primary sero-negative	Primary sero-positive	Secondary
Group A ..	209	15·2	27·8	20·5
Group B ..	228	54·3	60·6	45·2

TABLE VII
MEAN QUANTITIES OF ARSENIC AND BISMUTH RECEIVED PRIOR TO PENICILLIN THERAPY

Diagnosis	No. of cases	Mean dose N.A.B. (g.)	Mean dose bismuth (g.)	Mean duration of treatment (including penicillin) (months)
Primary: sero-negative	25	7·7 ±0·6	4·1 ±0·4	6·4 ±0·8
Primary: sero-positive	38	7·1 ±0·5	4·1 ±0·5	7·0 ±0·7
Secondary	26	7·9 ±0·7	4·8 ±0·6	7·1 ±0·1

TABLE VIII
SEROLOGY AT START OF PENICILLIN THERAPY

Initial diagnosis	No. of cases	Negative %	Positive %	Insufficient data %
Primary: sero-negative	25	100	0·0	0·0
Primary: sero-positive	38	64·1	10·3	25·6
Secondary	26	80·8	11·5	7·7

Cases which received *short-term arsenic therapy* fell into two groups. The first group comprised cases treated by daily intravenous injections of mapharside of 0·06 g. and intramuscular injection of bismuth over a period of 20 days. On inspection the cases consistently received a total of 2·0 g. bismuth and the treatment period was 20 days with

TABLE IX

Diagnosis	No. of cases	Mean dose mapharside (g.)
Primary: sero-negative ..	32	1·31
Primary: sero-positive ..	38	1·30
Secondary	42	1·29

TABLE X

PERCENTAGE RELAPSE RATES

Maximum values shown below were calculated by regarding *doubtful* cases as *relapses*, minimum values by regarding such cases as *cures*. Figures before the sign ∓ are thus the means of the maximum and minimum rates and include one half of the doubtful cases.

	Time period (months)	Pen. 2·4 Mu	Pen. 4·0 Mu	Pen. 2·4 Mu and maph. 0·6 g.	Pen. 2·4 Mu, maph. 0·4 g., bi. 1·0 g.	L.T.A. 7 g., pen. 2·4 Mu	L.T.A. (A) (N.A.B. 22 g. Bi. 9g.)	L.T.A. (B) (N.A.B. 14 g. Bi. 9g.)	S.T.A. (maph. 1·3 g., bi. 2·0 g.)
Primary sero-negative	6	11·0∓0·5	(10·8∓0·8)	14·6∓1·5	5·0∓0·0	(0·0)	0·0	0·0	0·0
	12	14·0∓2·4	—	(18·2∓1·5)	(9·0∓1·9)	(5·7∓0·0)	(0·0)	(0·0)	(0·0)
	18	(20·7∓2·2)	—	—	—	—	—	(0·0)	—
Primary sero-positive	6	10·2∓0·0	(6·3∓0·0)	6·7∓0·9	10·9∓0·0	2·6∓0·0	0·0	0·6∓0·6	5·3∓0·0
	12	12·8∓0·0	—	(15·9∓4·5)	(23·3∓3·3)	(2·6∓0·0)	1·6∓0·0	3·5∓0·6	(5·3∓0·0)
	18	(14·1∓1·3)	—	—	—	—	—	—	(17·8∓2·5)
Secondary	6	8·1∓0·5	(17·4∓0·0)	(6·6∓0·0)	(19·2∓0·0)	(8·8∓0·0)	4·1∓0·9	3·8∓1·2	5·7∓0·0
	12	17·5∓0·5	—	—	—	(12·9∓4·1)	(11·4∓2·1)	(9·3∓2·8)	(10·7∓1·5)
	18	—	—	—	—	—	—	—	(16·8∓3·7)

Bracketed figures are based on samples of less than 30 cases

exceptional and minor variations (e.g. ±0·2 g. bismuth and ±1 day respectively). Mapharside dosage varied between 1·2 g. and 1.6 g. for the course. Table IX shows, however, that the mean dosage was 1·3 g.

The second group comprised only about 40 cases treated by semi-intensive courses of mapharside, or neohalarsen, and bismuth over a minimum period of thirty days. The variability of dosage and treatment period were, however, too great to allow of standardization in such a small group of cases. We therefore present the relapse rates for the twenty-day treatment group only.

6. RESULTS

Appendix 1 cites crude figures with reference to relapses, and failures and doubtful cases; and Appendix 2 cites cases remaining at the end of specified intervals after end of treatment. Table X shows cumulative relapse rates at the end of six and twelve months for the different treatments. With regard to some, it was possible to follow sufficient cases for eighteen months. Figures can be regarded only as trends owing to the small size of some samples. All failures as defined above have been excluded. It is evident that the penicillin courses are comparatively unsuccessful except when following long-term arsenic. The two L.T.A. schemes are apparently the most efficient, particularly for treatment of primary syphilis, and in contrast to other forms of therapy are the most successful treatments of secondary syphilis. Short-term arsenotherapy takes an intermediate position.

It is interesting to note the comparative relapse rates of S.T.A. (mapharside 1·3 g. and bismuth 2·0 g.) with: (*a*) penicillin 2·4 mega units and mapharside 0·6 g., and (*b*) penicillin 2·4 mega units and mapharside 0·4 g. + bismuth 1·0 g. Duration of treatment was much the same for each of these therapies. The relapse rates of S.T.A. are consistently smaller than those of either form of combined therapy. The least difference occurred in cases of sero-positive primary and in cases of secondary syphilis between S.T.A. and penicillin 2·4 mega units and mapharside 0·6 g. Since penicillin alone, in the two dosage schemes investigated, is least efficacious of all, these relapse rates suggest that penicillin may in some way mitigate the effect of arsenic on *Treponema pallidum*. It is, however, necessary to point out that the dosage of mapharside received by the S.T.A. group was at least twice as great as that given to the penicillin cases.

TABLE XI

ANALYSIS OF TREATMENT FAILURE CASES

Percentage of treatment failure cases (defined as cases remaining persistently sero-positive for four months or more after treatment) as a percentage of total numbers of cases (within each treatment).

	Pen. 2·4 Mu	Pen. 4·0 Mu	Pen. 2·4 Mu and maph. 6·0	Pen. 2·4 Mu, maph. 0·4 g., bi. 1·0 g.	LTA 7 g. and Pen. 2·4 Mu	LTA (A) NAB 22 g. Bi. 9 g.	LTA (B) NAB 14 g. Bi. 9 g.	STA 1·3 g., bi. 2·0 g.
Primary sero-positive	2·9∓0·0	1·6∓1·6	0·8∓0·8	5·5∓0·8	0·0	0·0	0·0	0·0
Secondary	7·8∓3·2	3·8∓3·8	2·5∓2·5	2·8∓2·8	0·0	0·0	5·0∓0·0	10·7∓6·0

Our data sustain the accepted conclusion that the prognosis for arsenotherapy is less favourable if treatment does not start until the sero-positive primary stage. Contrary to results reported by Moore (1943) and others, they would also suggest that the prognosis for sero-positive primary cases is better than that for secondary cases. Our results do not suggest any consistent differences in these respects with regard to penicillin therapy. Although attenuation of our material owing to the introduction of penicillin shortly before demobilization compels us to state only guarded conclusions with respect to the long-term prognosis of penicillin therapy, the picture disclosed by the diagram suggests that the risk of relapse among cases treated in the primary stage reaches a limiting value of about 14 per cent. within the first twelve months.

Our definition excludes the occurrence of failures among sero-negative primary cases. Table XI shows an analysis of those cases remaining sero-positive for four or more months. Penicillin has a comparatively higher rate of failure among sero-positive primary cases, but among secondary cases, particularly when combined with mapharside, compares not unfavourably with S.T.A. and the smaller dosage group (B) of L.T.A. For most treatments the prognosis in this respect of secondary cases is less favourable than the prognosis of primary cases.

Summary

Relapse rates during a twelve-month period of cases of early syphilis respectively treated with eight different therapies are contrasted and disclose the following conclusions:

1. Long-term arsenic in a mean dosage of 22 g. N.A.B. given in four or more courses proved to be the most effective therapy for all forms of early syphilis. In dosages averaging 14 g. in fewer than four courses, it was the next most efficacious.

2. For primary cases in the doses, and for the period, specified in the text, penicillin alone was inferior to either long-term or short-term arsenotherapy both with respect to prognosis of relapse and resistance to treatment.

3. The data of this enquiry give no conclusive indications of synergism with reference to simultaneous use of penicillin and arsenicals with bismuth, being suggestive, if at all, of the reverse.

4. Though the data recorded admittedly antedate recognition of the importance of the K-fraction, the results at least emphasize the need for long-term follow-up before replacing arsenotherapy by penicillin.

5. On the other hand, it is necessary to admit the possibility that greater frequency and/or duration of penicillin treatment in contradistinction to greater aggregate dosage might reverse the unfavourable verdict which our data compel us to record.

We are indebted to the Director General, Army Medical Services, for permission to publish this paper, and to Prof. Lancelot Hogben, F.R.S., for much help and advice. Our thanks are also due to Lt.-Col. R. R. Willcox, R.A.M.C. and Lt.-Col. J. W. Eames, R.A.M.C., Advisers in Venereology to the Army, for their willing co-operation.

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APPENDIX 1

The relative distribution of relapses and treatment failures in the various treatment groups and their subdivision into primary sero-negative, primary sero-positive, and secondary cases. Space does not permit of indication of the relationships of relapses to time intervals after treatment. Crude figures.

	Primary sero-negative			Primary sero-positive					Secondary				
	Clin. relapse	Definite sero-relapse	Doubtful sero-relapse	Clin. relapse	Definite sero-relapse	Doubtful sero-relapse	Definite treatment failures	Doubtful treatment failures	Clin. relapse	Definite sero-relapse	Doubtful sero-relapse	Definite treatment failures	Doubtful treatment failures
Pen. 2·4 ..	11	1	3	15	3	1	4	0	8	4	2	5	7
Pen. 4·0 ..	5	0	1	1	0	0	0	1	2	1	0	0	1
Pen. and maph.	10	1	2	5	1	3	0	1	3	0	0	0	2
Pen., maph., and bi.	5	0	1	6	1	1	3	1	6	1	0	0	2
LTA and pen.	2	0	0	2	0	0	0	0	0	3	1	0	0
LTA (A) ..	0	0	0	0	1	0	0	0	0	0	6	0	0
LTA (B) ..	0	0	0	1	1	0	0	0	0	4	0	2	0
STA	0	0	0	2	2	2	0	0	1	5	0	2	5
Total	33	2	7	32	9	7	7	3	20	18	9	9	17

APPENDIX 2

Numbers of cases in each treatment group (subdivided into primary sero-negative, primary sero-positive, and secondary) and the numbers of cases remaining under surveillance after six and twelve months.
It will be noted that relatively small numbers of cases in the LTA, LTA+Pen., and STA groups were, in general, followed over a longer period than the other cases.

		Pen. 2·4	Pen. 4·0	Pen. and maph.	Pen., maph., and bi.	LTA and pen.	LTA (A)	LTA (B)	STA	
Primary sero-negative	Total treated	114	57	108	105	25	44	75	32	
	Remaining 6/12	80	20	30	51	23	30	64	31	
	Remaining 12/12	41	0	6	5	8	10	34	23	
Primary sero-positive	Total treated	163	41	110	89	38	84	84	38	
	Remaining 6/12	122	14	31	42	31	64	63	35	
	Remaining 12/12	52	0	6	2	17	31	31	29	
Secondary	Total treated	118	28	53	48	26	67	46	42	
	Remaining 6/12	86	8	25	20	19	48	36	39	
	Remaining 12/12	32	0	5	4	9	26	20	28	Total cases
Total treated		395	126	271	242	89	195	205	112	1,635

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STUDIES ON PUBERTY. PART I

BY

HAMILTON HOGBEN, J. A. H. WATERHOUSE, and LANCELOT HOGBEN

1. Introduction

Existing literature concerning the onset of human sexual maturity is more extensive with respect to the female than to the male. This is not surprising, in so far as the menarche is an event more abrupt than any change characteristic of puberty in the male, and one with more far-reaching social consequences. Whilst there is no shortage of recorded data with respect to the menarche, their value is by no means uniform. Many published enquiries admittedly refer to statements about its onset communicated by subjects concerned after a more or less protracted interval, with or without ancillary confirmation from other sources (for example, the mother). To this category belong, *inter alia*, such accounts as those of Barker and Stone (1936), Bersamin and Gonzales-Bersamin (1940), Boas (1932), Ito (1942), Kark (1943), Kennedy (1933), Michelson (1944), Mills (1941 a and b), Mills and Chenoweth (1938), Simmons and Greulich (1943), Stone and Barker (1937). Other authors either fail to state explicitly whether they took any steps to verify the asserted date of occurrence of the event, or are insufficiently explicit about the type of verification they sought. Among such we may mention Borruat (1941), Gómez (1942), and Pryor (1936). Aside from uncertainties arising from undue reliance on personal testimony in contradistinction to direct observation, many published accounts are of limited usefulness owing to the nature of the sample selected for the purpose. For instance, some refer to experience of patients at clinics or in hospitals. Among the very few authors who have studied a more truly representative population sample and have recorded only the results of direct observation, in contradistinction to assertions made by the subjects themselves, are Bayer (1940) and Engle and Shelesnyak (1934).

Of all the literature we have had access to, none dealing with the menarche makes available a continuous picture of concomitant physical changes, such as enlargement of the breasts and proliferation of pubic or axillary hair; but several authors have attempted to relate onset of menstruation to skeletal changes of adolescence or to anthropometric measurements. Among such are Barker and Stone (1936), Bayer (1940), Boas (1932), Ito (1942), Michelson (1944), Pryor (1936), Simmons and Greulich (1943), and Stone and Barker (1937). More recently Shock (1941-46) has recorded age-changes and sex differences in adolescence with respect to blood pressure, pulse rate, basal metabolic rate, alveolar carbon dioxide tension, and excretion of sex hormones. Curiously enough, there has been little attention to such metrical indices as more especially signalize sexual dimorphism, for example shoulder and pelvic width, neck girth, etc. Recent papers by Borruat (1941) and by Schonfeld (1943) on pubescence sufficiently emphasize how defective is our knowledge concerning sequence and duration of the several manifestations accompanying maturation of the male gonads. Most of the literature dealing with the male at present available is indeed of very doubtful scientific value by the very nature of the methods on which it relies. A noteworthy exception is a substantial contribution by Ellis (1946). For neither sex can we turn to accessible information which discloses a panoramic picture of sexual maturation exhibiting changes of form and function during the period between childhood and the attainment of maturity on a chronological time scale. Such a complete survey of the process of sexual maturation should show the order in which the changes take place, the duration of each phase, and the range of normal variability, as well as the inter-relationships of the different phases.

Several authors have discussed variation with respect to onset of puberty *vis-à-vis* extrinsic and intrinsic agencies; but a satisfactory analysis of the relevant variables, genetic, climatic, nutritional, or other, calls for more searching investigation of the sequence of phenomena and the variability to which they are subject in a fairly homogeneous population than information at present available in the literature of the subject can supply. There appears to be a widespread belief that considerable differences with regard to the time of onset of puberty separate stocks of different ethnic origin, but available

records referring to different ethnic stocks domiciled under comparable climatic conditions do not disclose spectacular or even significant discrepancies. Authors such as Kennedy (1933), Klineberg (1935), Fluhmann (1936), and others who have reviewed the literature available concur in recognizing that such differences are dubious, or at best, small. Michelson (1944) has published data about the menarche in several sample populations of both whites and negroes, including in all about 7,000 subjects. For different samples of whites, the age means extended over the range 13·08 to 13·62 years. For different samples of negroes, they extended from 13·35 to 13·99. When we give due weight to the uncertainty arising from undue reliance on the memory of the individual subject, we can hardly place great confidence in the conclusion that menarche of negroes is later than it is in whites. In any case, Michelson found no significant difference between such samples as were comparable with regard to socio-economic status and age at the time of questioning. In view of the highly dubious and at least trivial nature of differences attributable to ethnic origin, as such, we might expect to find a greater unanimity of testimony with regard to effects of climate. Contrary to the view commonly expressed in medical textbooks, writers who have lately reviewed the subject incline to the conclusion that hot climates delay the menarche.

In this connexion we may mention the writings of Kennedy (1933), Mills and Chenoweth (1938), Howe (1939), Ito (1942), Mills (1937, 1941 a, b, 1944), Kark (1943), Bersamin and Gonzales-Bersamin (1940), and Kark (1943). These authors concur in the definite assertion that menarche occurs later in the tropics than in temperate regions. Whilst their data are open to criticism on grounds stated above, they are at least as reliable as any cited to sustain the earlier and still prevalent belief that a warm environment favours early sexual maturity of the human female. The issue is one which clearly invites further enquiry, and it is regrettable that there are no statistically plausible data with respect to the male subject.

Attempts to probe the role of nature and nurture by comparisons between the age at menarche of mothers and daughters and the age at menarche of sisters, as by Bolk (1923) and by Gould and Gould (1932) are suggestive but inconclusive, if only because they rely on personal testimony of an event long after its occurrence. For the same reason, we may dismiss a copious literature by Mills (1937-44) and others attesting to a supposedly secular change of the date of menarche putatively associated with change of the social or physical environment. It is not unlikely that the alleged secular trend signifies nothing more than a systematic error of memorization. Authors who have investigated age at menarche in different social classes incline to the view that girls of the more prosperous sections of the community develop earlier. Among those who have directed attention to this class of variables are: Bersamin and Gonzales-Bersamin (1940), Fluhmann (1936), Kark (1943), Kennedy (1933), and Klineberg (1935), among other authors.

Authors who have made concomitant anthropometric observations have drawn attention to one or other of the following general conclusions:

(i) there is a rapid growth period in the six months before onset of menstruation;

(ii) the gain in height at this time precedes gain in weight;

(iii) women with later menarche continue to increase in weight and height more rapidly than early pubescents;

(iv) women who menstruate later therefore grow for a longer period, become taller and tend to the leptosomate build, while those who menstruate earlier stop growing earlier and tend to the pycnic build.

There is little basis for comparison between the sequence of some of the most characteristic signposts of puberty in man and the course of sexual maturation in man's nearest allies. The delayed and highly localized appearance of copious hair other than that of the scalp is highly characteristic of man himself, as the localized alopoecia and coloration of the buttocks is highly characteristic of the catarrhines. Yerkes (1943) cites the following figures for the approximate age range of pubescence (both sexes):

Gibbon and siamang	5- 8 years
Orang utan and chimpanzee ..	8-12 ,,
Gorilla	10-14 ,,

These figures suggest no sharp break between the apes and man. Information with respect to the gorilla is fragmentary, but Yerkes asserts that the female gorilla does not mature until over seven years. Since menarche of the human female may occur before nine years of age, we may infer that the dates of sexual maturation in the two species overlap appreciably. In Yerkes' laboratory, chimpanzees matured at seven to ten years, earlier than in records referable to more natural conditions. Zuckerman's observations (1932) on the course of pubescence with special reference to the sexual skin of the chimpanzee show that it is protracted, lasting about two years. As regards monkeys, Hartman (1931) dates the beginning of menstruation

of the *rhesus* macaque at four years. Yerkes gives the same age for the Chacma baboon, but Zuckerman had reported on a male Hamadryas still immature after four and a half years' captivity. Dr. Peter Eckstein (private communication) informs us that the onset of menarche in *rhesus* monkeys of known age in his experience is between 2¼ and 3 years.*

2. Scope of Enquiry

The immediate object of the present enquiry is: (*a*) to provide a picture of the sequence of changes associated with puberty in both sexes, with special reference to sexual dimorphism; (*b*) to examine variability with reference to both the onset and the duration of each phase in a relatively homogeneous population sample. It relies exclusively on *direct* observations of the subjects by a medically qualified investigator in the course of routine medical inspection of schoolchildren.†

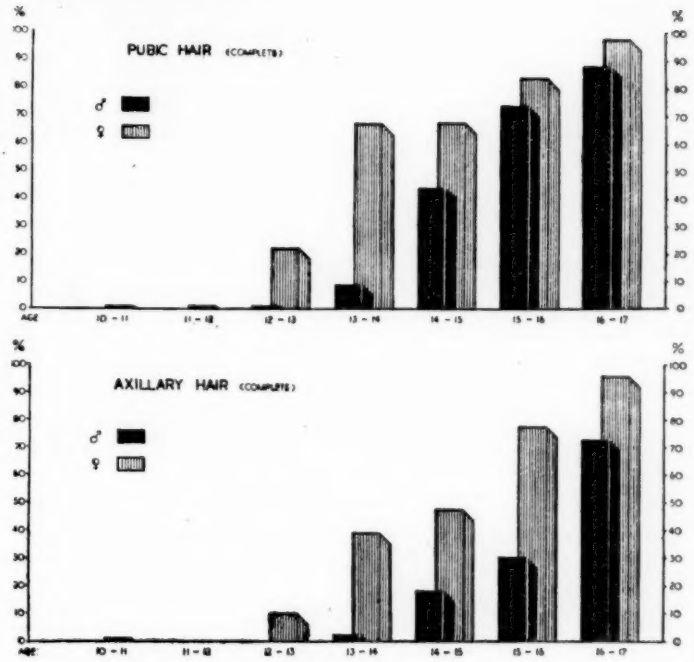

FIG. 1.—Representation of cumulative percentages of children in successive age groups with full development of pubic and axillary hair. Boys (black) superimposed on girls.

The ideal method of securing information of this kind would involve follow-up of each individual over a period including the beginning and the completion of the period of sexual development; but this procedure would necessitate a very protracted enquiry beset by many practical difficulties, unless based on small samples as in Shock's enquiries cited above. Accordingly, we have adopted an alternative plan, viz. that of recording the level of development reached by each child in a sample taken from each of a sequence of half-yearly age groups starting at eight and a half years. By this means, it is possible to assess (*a*) what proportion of individuals in a given age group have already reached a level defined by the presence or absence of a particular attribute of sexual maturation; (*b*) for each such age group the mean value of any metrical index relevant to morphogenetic divergence during sexual maturation.

The size of the sample examined was 900 girls and 850 boys, but the numbers of records which were wholly satisfactory were respectively 662 and 642. Children of the older age groups attended one or other of the secondary (grammar) schools in the Borough of Tottenham; children of the lower age group attended primary schools of the borough under the same authority. The selected borough is itself a relatively homogeneous community with respect to socio-economic level, and the investigators used personal knowledge of the local set-up to draw on local primary schools providing instruction for children of families at a socio-economic level most nearly comparable to that of families from which the secondary schools themselves recruit their personnel.

The ultimate aim of the investigation takes within its scope an issue of wider interest than stated above. Design of the records provided for collecting: (*a*) information concerning school progress, health and social habits of the children; (*b*) anthropometric data which may later provide the basis of a *typological* prognosis of early or late sexual development. At this stage, however, our concern is solely with the issue stated above. To that end the record of every child examined cited its age and sex grading with respect to certain qualitative attributes as specified below, and measurements to clarify such sexual dimorphism as dates especially from pubescence. It is a matter of common observation that the hips of the adult female are relatively wider than those of the adult male, and that the neck of the adult male is relatively thicker than that of the female before the menopause. We have concentrated our attention on this

* Since writing the above, the authors have received the *Edinburgh Medical Journal*, vol. 54, June, 1947, containing a useful contribution by R. W. B. Ellis, with the title "Growth in Relation to Maturity."

† We acknowledge our great indebtedness to the Education Committee of the Borough of Tottenham, and to its Education Officer, to the Principals of the Schools in which examinations took place, to Dr. Norah Webster of the Public Health Department of the Borough, for collaboration in examining the children, to Mr. R. Cawley for invaluable assistance in sorting the data, and to Miss Gladys Haines for preparation of charts.

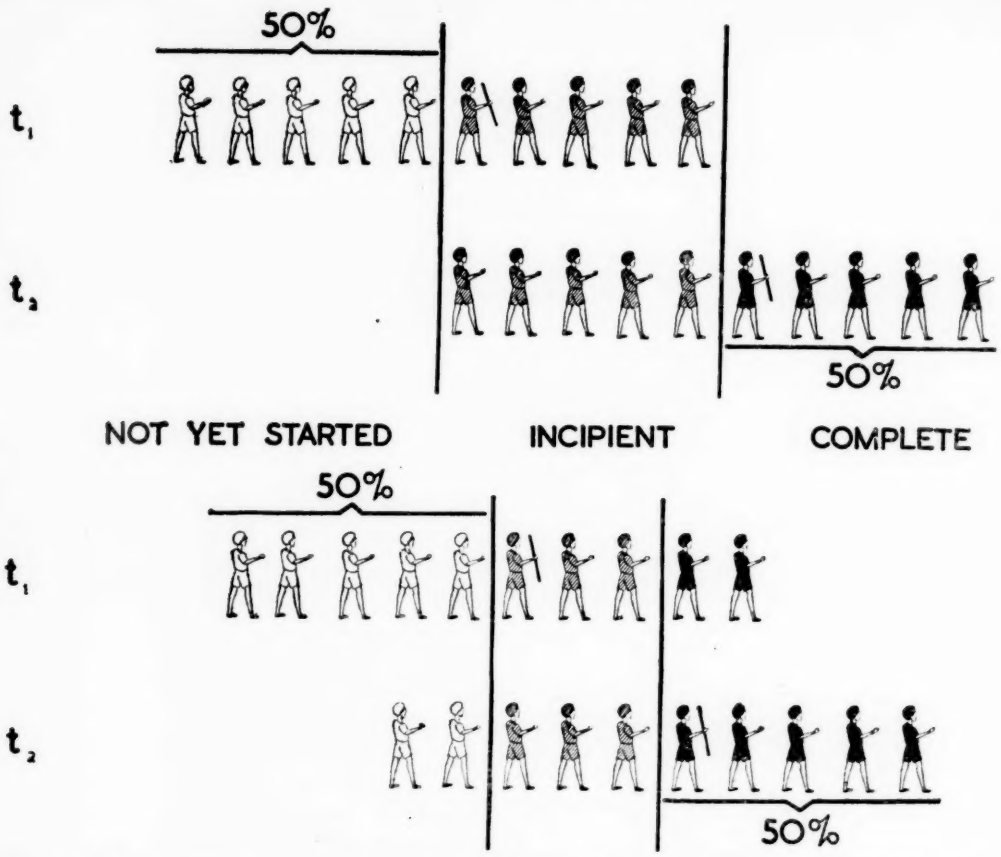

FIG. 2.—Diagrammatic representation of mean duration of development of characters amenable to specification by threefold split.

dimorphism, using as background data height, weight, trunk length, and shoulder (bisacromial) width. The qualitative attributes recorded by grades were as follows:

Hair-growth:

(*a*) *pubic*	absent	short	copious
(*b*) *axillary*	absent	short	copious
(*c*) *chin*	absent	short	copious
(*d*) *upper lip*	absent	short	copious

Contour of pubic hair:

apical intermediate horizontal

Breasts:

(*a*) rudimentary	enlarging	full
(*b*) nipple retracted	nipple normal	

Menstruation:

(*a*) already	not yet
(*b*) regular	irregular

Testes:

retractile non-retractile

Voice:

unbroken breaking broken

Prepuce:

removed incomplete complete

Seminal activity:

already not yet

Urine:

with albumin without albumin

It will suffice to say that reliable records of the penultimate item proved to be unobtainable and the exigencies of school routine limited opportunities for getting a sufficient sample of the last. In addition to items mentioned, and to a variety of other anthropometric data not relevant to the subject matter of this communication, the records covered included various qualitative attributes, e.g. eye and hair colour, other than those which distinguish the sexes. The main issues with which we are here concerned are:

(1) the mean age, and its variance at the appearance of each of the following characteristics: pubic hair, axillary hair, enlargement of

breasts, retention of the testes in the scrotum, enlargement of the larynx, appearance of hair on chin and upper lip;

(2) the *duration* of the changes involved in the appearance of the characteristics above mentioned;

(3) delimitation of the date of the menarche;

(4) differentiation of pubic hair contour;

(5) differentiation of hip width and neck growth.

For the purpose of specifying date of closure of the inguinal canal, the procedure was as follows: On failure of the boy to accomplish voluntary retraction into the inguinal canal in the prone position, the examiner ascertained by gentle palpation in turn if either testis could be made to pass through the external abdominal ring. It is of minor interest to record in this context some information with reference to the condition of the prepuce among the boys. For the purposes of the ensuing three-fold split, "removed" signifies that circumcision had been carried out. Incomplete signifies that the foreskin did not extend to the top of the glans in its normal condition.

Removed	.. ..	$26{\cdot}4 \pm 1{\cdot}8$
Incomplete	.. ..	$8{\cdot}1 \pm 1{\cdot}1$
Complete	.. ..	$65{\cdot}5 \pm 1{\cdot}9$

3. Computation of Age Distributions

The raw data of this enquiry supply us with the means of plotting graphs which exhibit the incidence of a given attribute of sexual development in equally-spaced intervals of time. In a graph or histogram so constructed, age is in effect the independent variable with respect to which y, the percentage exhibition of the individual character, is the dependent one. To assess the course of events, either in terms of median age, or for the purpose of estimating the duration of the process of sexual

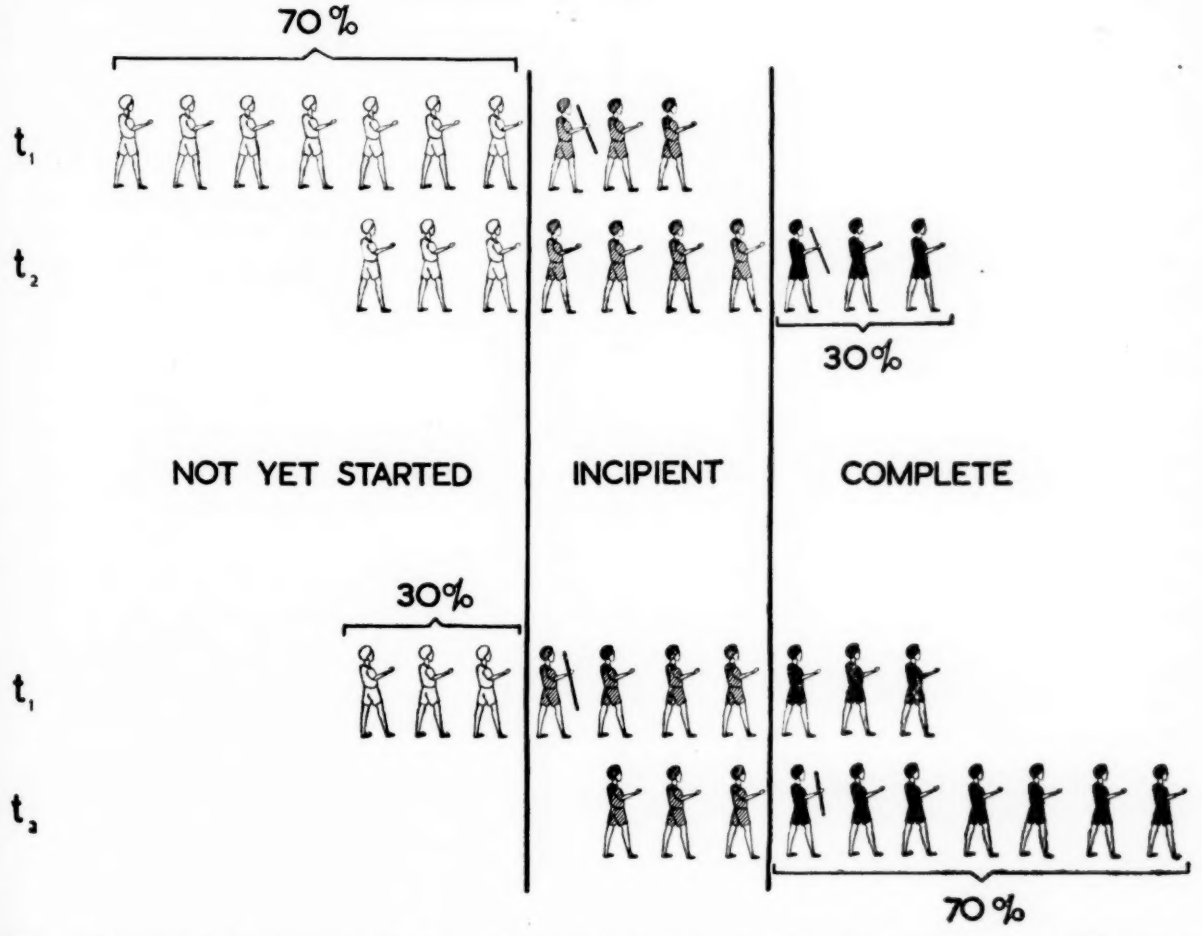

FIG. 3.—Diagrammatic representation of mean duration of development of characters amenable to specification by threefold split.

differentiation, what we need to know is at what age any given proportion of the population sample has attained a specified level of development. In other words, the question to which we seek an answer presupposes that we can express age (y) as the dependent with respect to percentage incidence (x) as the independent variable.

Cumulative percentage graphs of the incidence of a qualitative characteristic of puberty derived from the raw data, as in Fig. 1, are of a sigmoid type. For estimation of age in terms of decile incidence-levels, *e.g.* the age at which exactly 70 per cent. of girls have attained the menarche, we have employed two types of sigmoid curve to fit the data in accordance with the requirements stated in the preceding paragraph: (*a*) a logistic; (*b*) a probit, that is, integral normal.

(*a*) Logistic curves are here defined (on a percentage scale) by the following equation in which y, the dependent variable, is the age, and x is the percentage exhibition:

$$x = \frac{100}{1 + e^{a - by}} \qquad \text{(i)}$$

The numerical work of fitting curves of this type to our raw data was carried out by Dr. L. J. Comrie and his staff of the Scientific Computing Service. As it stands, the form of (i) is not suitable for least squares calculation of a and b. We therefore write:

$$e^{a - by} = \frac{100 - x}{x} = x'$$

$$(a - by) = \log_e x' = X$$

We are thus left with a simple linear regression equation whose solution involving n, the number of yearly age groups, is:

$$b = -\frac{n\Sigma Xy - \Sigma X \Sigma y}{n\Sigma y^2 - (\Sigma y)^2}; \quad a = \frac{\Sigma X + b\Sigma y}{n}$$

Observations involving 100 per cent. or 0 per cent. values are useless for fitting, since they involve indeterminate equations. For the actual computations of a and b, the two subsidiary variables, x′ and X, are calculated from x, and tabulated. For the reasons stated above, n is never greater than 8. To obtain the deciles, for which x = 10, 20, ... 90, again x′ and X are tabulated, and the corresponding values of y found from the equation.

(*b*) The computation of an age distribution with respect to decile development levels by the alternative method was carried out for us by the Mathematics Division of the National Physical Laboratory. The assumption inherent in this method is that we may regard the sigmoid which embodies the raw data as the integral of a normal distribution. From the observed percentage values, x, the probits or normal deviates, Y, corresponding to these percentages are obtained from probit tables. These values, Y, plotted against the values of the independent variable, y, should give a straight line if the assumption of normality is correct. Again a regression line is computed, and hence a better approximation obtained. The National Physical Laboratory used this method of successive approximation to obtain maximum likelihood estimates of the mean age, standard deviation, and deciles. Besides giving the decile values for the ages, we are thus able to cite the fiducial limits at P = 0·95 for the mean, standard deviation, and extreme deciles, as also the criterion of goodness of fit χ^2 together with the critical value $_0\chi^2$ against which it is judged.

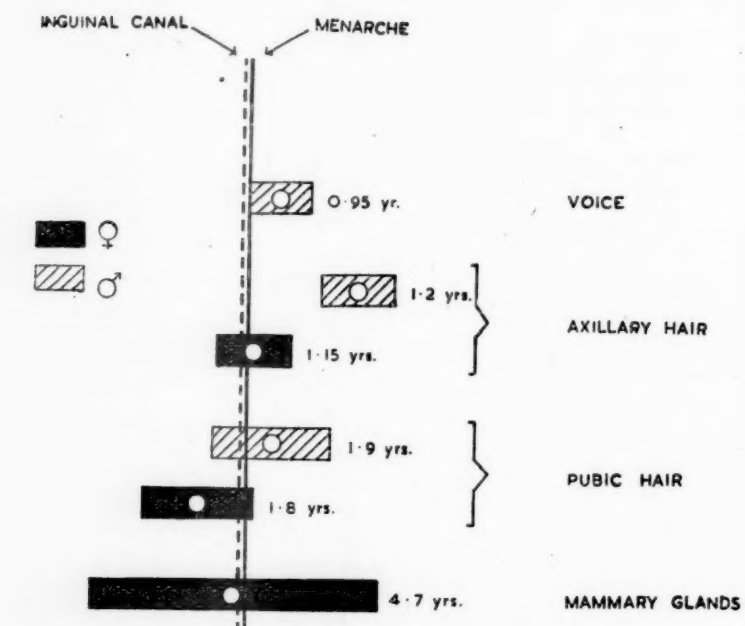

FIG. 4.—Duration and median age of metamorphosis with respect to sexually-differentiated characteristics.

TABLE I

ESTIMATED MEDIAN AGES WITH SEMI-INTERQUARTILE RANGE (YEARS)

	(*a*) Logistic fit		(*b*) Probit fit	
	50% infantile at:	50% adult at:	50% infantile at:	50% adult at:
(*a*) *Girls*				
Mammary glands ..	11·0 ± 0·75	15·8	11·5 ± 0·83	16·1 ± 1·45
Pubic hair	11·8 ± 0·7	13·7 ± 0·87	12·4 ± 0·83	14·1 ± 0·95
Axillary hair	13·2 ± 1·0	14·2 ± 0·92	13·5 ± 1·03	14·8 ± 1·0
Menarche	13·6 ± 0·77	14·3 ± 1·25	14·0 ± 0·75	14·8 ± 1·05
(*b*) *Boys*				
Pubic hair	12·9 ± 1·05	15·0 ± 0·67	13·6 ± 1·05	15·3 ± 0·75
Inguinal canal	13·5 ± 1·0	13·6 ± 0·95	13·9 ± 0·95	14·1 ± 0·95
Voice	13·6 ± 0·97	14·5 ± 0·37	14·0 ± 0·83	15·0 ± 0·4
Axillary hair	14·8 ± 0·85	16·0 ± 0·63	15·2 ± 0·95	16·4 ± 0·6
Hair of upper lip ..	15·5 ± 1·0		15·7 ± 0·85	
Hair of chin	16·0 ± 0·75		16·5 ± 0·75	

We have reason (see section 5 below) to believe that the logistic formula accords more closely with the trends it describes than does the probit curve, of which the rationale rests on an entirely arbitrary assumption, viz. a normal distribution of the proportion of individuals of a given age group attaining a given level of maturity. Though this postulate is attractive from a statistical point of view, it would be difficult to justify on biological grounds.

4. THE CRITICAL AGES

Each of the attributes specified in Table I admits a distinction between: (i) the infantile condition; (ii) a transitional stage; (iii) the fully-developed or adult state. In defining a mid-point of a gross process on the basis of this split, we may therefore adopt one or both of two criteria: (*a*) the time at which half the population is still infantile; (*b*) the time at which half the population is already adult. For example, we may estimate a time at which: (i) 50 per cent. of our sample have no pubic hair and 50 per cent. have an incipient or copious growth; (ii) 50 per cent. of our sample have a copious pubic hair and 50 per cent. have either none or merely a poor growth.

We refer to these two critical ages in Tables I, IV, and VI respectively as the *median age at which 50 per cent. are infantile* and the *median age at which 50 per cent. are adult* with respect to a specified characteristic. The corresponding semi-interquartile ranges are bounded by the 25 per cent. and 75 per cent. levels. Needless to say, direct inspection of our data does not permit us to specify either the one or the other. It merely permits us to tabulate the proportions of the three classes in each age group. Such tabulations supply us with the raw data to which it is possible to fit distributions which permit us to treat the percentage of infantile or the percentage of adult types as the independent variable and hence to compute an estimated date at which 10 per cent., 20 per cent., etc., of the total population are still infantile or are already adult with respect to a particular characteristic. Table I sets forth the two critical ages as above defined in accordance with two different methods of interpolation.

Our data record whether girls examined were menstruating regularly or not. If we reject individuals who have not yet menstruated or have done so only once, we may divide those who have attained the menarche into two fairly clear-cut categories from this point of view. Table II shows a threefold age split of this residual sample. Since the proportion of girls with irregular periods diminishes from the menarche onwards, we may infer that an appreciable proportion of all girls pass through a stage of irregular menstruation before attaining regularity; but it would not appear that such a stage invariably follows the menarche. Consequently our data under this heading do not justify a threefold split *en rapport* with those referring to other phenomena of sexual maturity exhibited in Table I.

TABLE II

INCEPTION OF MENSTRUATION

Age group (years)	Period irregular %	Period regular %	Total
$<12\frac{1}{2}$	25	75	100
$12\frac{1}{2}$—$14\frac{1}{2}$	20	80	100
$14\frac{1}{2}$—$16\frac{1}{2}$	15	85	100

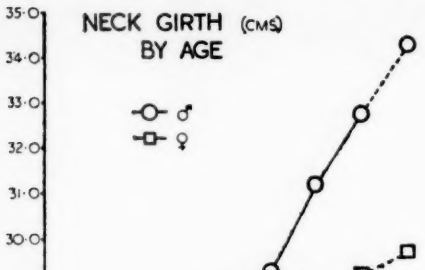

FIG. 5.

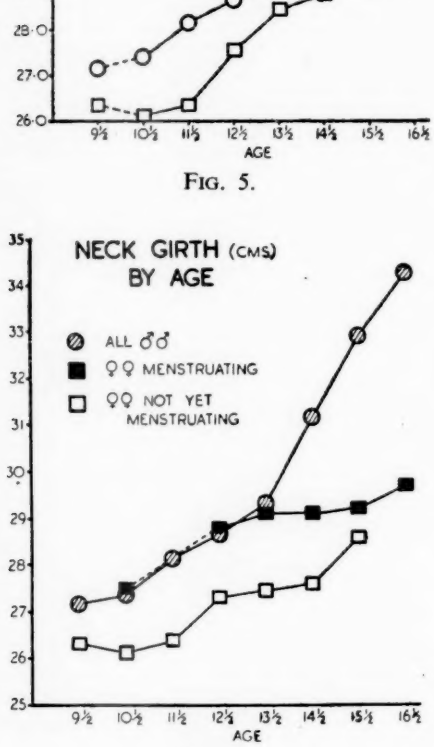

FIG. 6.

5. DURATION OF PUBESCENCE

The critical ages defined in section 4 provide us with signposts of the temporal *order* of the several phenomena involved in sexual maturation. We now have to ask whether our data can supply us with any information concerning the *duration* of the manifest processes. It would appear that this is possible with respect to such attributes as are classifiable in three grades specified above, viz. (*a*) *not yet started* (*infantile*); (*b*) *incipient* (*maturing*); (*c*) *complete* (*adult*). The analogy of a procession marching at uniform speed in single file along an avenue with gates at either end suggests a positive answer.

Individuals specifiable in this context as *not yet started* are comparable to individuals who have not yet entered the near gate, *incipients* to those who are

FIG. 7.

TABLE III

DURATION OF STAGES (YEARS) BASED ON THE 50 PER CENT. LEVEL

	(*a*) Logistic fit	(*b*) Probit fit
(*a*) *Girls*		
Mammary glands ..	4·8	4·6
Pubic hair	1·9	1·7
Axillary hair	1·0	1·3
(*b*) *Boys*		
Pubic hair	2·1	1·7
Inguinal canal*	0·1	0·2
Voice ..	0·9	1·0
Axillary hair	1·2	1·2

* The figures cited here signify the period which elapses between occlusion of one side and occlusion of the other.

TABLE IIIA

COMPARISON OF ESTIMATES OF DURATION OF STAGES (YEARS) BASED ON THE LOGISTIC FIT

	Estimate A 30% level	Estimate B 50% level	Estimate C 70% level
(*a*) *Girls*			
Mammary glands ..	4·0	4·8	—
Pubic hair ..	1·7	1·9	1·9
Axillary hair..	1·1	1·0	1·0
(*b*) *Boys*			
Pubic hair ..	2·4	2·1	1·8
Inguinal canal* ..	0·2	0·1	0·1
Voice ..	1·1	0·9	0·1
Axillary hair..	1·3	1·2	1·0

* See remarks in footnote to Table III.

still between the two gates, and the *adult* class to those who have passed through the far gate. If exactly 50 per cent. of the procession has not yet entered the near gate (Fig. 2) at a time $t_1 = t_{50}$, and exactly 50 per cent. have passed the far gate at a time $t_2 = t_{50} + \triangle t_{50}$, the difference ($\triangle t_{50}$) is the time taken for an individual to complete the process of passing through the avenue. More generally (Fig. 3) we may suppose that exactly x per cent. have not yet entered the near gate at time $t_1 = t_x$, and that exactly y per cent. have passed out of the far gate at $t_2 = t_y$. The time taken for an individual to complete the course between the two gates is $t_y - t_x$, if $y = 100 - x$. The assumption that speed is uniform is, of course, arbitrary and certainly inapplicable to our problem; but the above considerations suggest that $t_y - t_x$ is a representative estimate of the duration of a manifest transformation of the type under consideration. That is to say, the mean interval involved is the difference between: (*a*) the age at which exactly x per cent. individuals do not as yet exhibit detectable manifestations of the adult trait; (*b*) exactly (100—x) per cent. are fully mature.

The threefold split which our data permit with respect to the closure of the inguinal canal, that is, both retractile, right or left only retractile, and neither retractile, do not correspond with the three stages specified above as infantile, maturing, and adult. Accordingly, the time interval specified in Tables III and IIIA with respect to the inguinal canal does not signify the duration of the process of occlusion. What it does signify is the interval between completion of occlusion of the canal on one side and that of occlusion of the inguinal canal on the other side.

Table III shows estimates of duration of stages based on the 50 per cent. level separately in accordance with the logistic formula and the probit formula. Table IIIA, which refers to the logistic method, shows different estimates respectively consistent with taking x as 30 per cent. (A), 50 per cent. (B), and 70 per cent. (C). The three separate estimates derived from the probit fit exhibit a systematic error inasmuch as the B estimate (50 per cent. level) consistently lies between the A and C estimates for a given character. On this account we regard the logistic formula as a more satisfactory descriptive device than the alternative specified in paragraph 3 above.

6. Quantitative Criteria of Sexual Dimorphism

In the course of examining our data with respect to two outstanding quantitative criteria of sexual dimorphism, namely neck girth and hip width, we computed several indices relating the relevant measurements to growth along other axes. For this purpose we took (*inter alia*) as our standard of

TABLE IV

Relation of Physique to Median Age (Years)—Girls (with Semi-interquartile Range)

	IA: Tall	IB: Short	IIA: Heavy	IIB: Light
	(*a*) Logistic estimate			
(i) 50% *Infantile*				
Mammary glands ..	11·0 ±0·75	11·5 ±1·00	11·0 ±0·75	11·0 ±0·63
Pubic hair	11·3 ±0·65	12·5 ±0·60	12·5	12·1 ±0·70
Axillary hair	12·6 ±1·07	13·7 ±1·00	12·8 ±0·90	13·3 ±1·13
Menarche	13·0 ±0·75	14·0 ±0·75	13·4 ±0·75	13·5 ±1·25
(ii) 50% *Adult*				
Mammary glands ..	15·7 ±2·00	16·0 ±2·05	14·5 ±1·75	(16·8)
Pubic hair	13·3 ±0·75	14·5 ±1·00	13·4 ±0·68	13·5 ±1·35
Axillary hair	14·0 ±1·05	15·0 ±1·00	14·0 ±0·85	14·5 ±1·20
Menarche	13·8 ±1·35	14·8 ±1·05	14·4 ±0·90	14·5 ±1·52
	(*b*) Probit estimate			
(i) 50% *Infantile*				
Mammary glands ..	11·1 ±0·75	11·8 ±0·83	11·0 ±1·1	11·8 ±0·57
Pubic hair	11·8 ±0·8	13·0 ±0·65	12·3 ±0·97	12·5 ±0·70
Axillary hair	13·0 ±0·95	14·1 ±0·97	13·3 ±0·95	13·7 ±1·12
Menarche	13·6 ±0·7	14·4 ±0·73	(13·8)	14·1 ±0·87
(ii) 50% *Adult*				
Mammary glands ..	16·3 ±1·6	16·1 ±1·3	15·3 ±1·05	17·4 ±2·05
Pubic hair	13·5 ±0·9	14·7 ±0·93	13·8 ±0·65	14·4 ±1·23
Axillary hair	14·5 ±0·97	14·7 ±0·93	14·4 ±0·8	15·2 ±1·17
Menarche	14·4 ±1·05	15·2 ±1·05	14·5 ±0·95	15·1 ±1·2

TABLE V

RELATION OF PHYSIQUE TO DURATION (YEARS) (50 PER CENT. LEVEL)—GIRLS

	IA	IB	IIA	IIB
	(*a*) Logistic estimate			
Mammary glands ..	4·7	4·5	3·5	(6·0)
Pubic hair	2·0	2·0	0·9	1·4
Axillary hair	1·4	1·3	1·2	1·2
	(*b*) Probit estimate			
Mammary glands ..	5·2	4·3	4·3	5·6
Pubic hair	1·7	1·7	1·5	1·9
Axillary hair	1·5	0·6	1·1	1·5

comparison weight, full height, and trunk length. As regards our immediate objective, these exploratory computations added little or nothing to the picture disclosed by the absolute measurements themselves; but they served to focus attention on a striking difference with respect to growth along the bisacromial axis. In this context we shall therefore confine our attention to direct measurements, deferring for a later communication the analysis of relative growth in terms of axial gradients. The salient differences are as follows:

(*a*) *Neck girth.* Within the age range covered by the investigation, the mean neck girth of the male (Fig. 5) is greater than that of the female of the same age, but the growth curves diverge noticeably in the fourteenth year, which signalizes a phase of more active growth of the male neck.

(*b*) *Pelvic width.* Until the thirteenth year, there is no consistent difference (Fig. 8) between the mean pelvic hip width of the girls and boys of our sample. Thenceforward, in each age group, the absolute mean of the hip width of the female is greater than that of the male of the same age. This is because the pubescence of the male signalizes the onset of a phase of slower growth with respect to the transverse width of the pelvis.

(*c*) *Bisacromial width.* At all ages in the range of this enquiry, the mean absolute shoulder width (Fig. 11) of the girl is greater than that of the male, and there is no sharp divergence associated with

TABLE VI

RELATION OF PHYSIQUE TO MEDIAN AGE (YEARS)—BOYS (WITH SEMI-INTERQUARTILE RANGES)

	IA: Tall	IB: Short	IIA: Heavy	IIB: Light
	(*a*) Logistic estimate			
(i) 50% *Infantile*				
Pubic hair	12·5 ±1·00	13·4 ±1·15	12·9 ±1·20	13·5 ±1·17
Inguinal canal	12·9 ±0·93	14·1 ±1·00	12·6 ±0·73	14·2 ±1·00
Voice	14·0	13·5 ±1·07	14·0	14·0 ±1·25
Axillary hair	14·5 ±0·63	15·5 ±1·10	14·2 ±0·78	15·5 ±0·95
Hair of upper lip ..	15·0 ±0·87	15·5 ±0·87	14·5 ±0·75	16·0 ±0·63
Hair of chin	16·0 ±0·75	16·5 ±0·63	15·5 ±0·75	16·5 ±0·63
(ii) 50% *Adult*				
Pubic hair	14·5 ±0·63	15·5 ±0·87	14·0 ±0·50	15·5 ±0·75
Inguinal canal	13·1 ±0·93	14·3 ±0·97	12·9 ±0·75	14·3 ±1·05
Voice	—	—	—	—
Axillary hair	15·5 ±0·63	16·5	15·0 ±0·63	16·5
	(*b*) Probit estimate			
(i) 50% *Infantile*				
Pubic hair	13·2 ±1·0	14·0 ±1·1	13·1 ±0·92	14·1 ±1·15
Inguinal canal	13·5 ±0·9	14·4 ±0·9	13·3 ±0·82	14·6 ±0·92
Voice	13·6 ±0·8	(14·4)	13·6 ±0·75	14·4 ±0·85
Axillary hair	14·7 ±0·67	15·9 ±1·12	14·6 ±0·75	16·0 ±1·0
Hair of upper lip ..	15·3 ±0·77	16·2 ±0·9	15·2 ±0·72	16·4 ±0·85
Hair of chin	16·2 ±0·72	16·9 ±0·7	16·1 ±0·27	16·9 ±0·65
(ii) 50% *Adult*				
Pubic hair	14·9 ±0·57	15·8 ±0·8	14·7 ±0·5	16·1 ±0·77
Inguinal canal	13·6 ±0·9	14·5 ±0·82	13·5 ±0·8	14·6 ±0·9
Voice	14·8 ±0·37	15·3 ±0·35	14·6 ±0·32	15·4 ±0·25
Axillary hair	15·9 ±0·72	17·0 ±0·92	15·8 ±0·7	17·1 ±0·82

TABLE VII

RELATION OF PHYSIQUE TO DURATION (YEARS) (50 PER CENT. LEVEL)—BOYS

	IA	IB	IIA	IIB
	(*a*) Logistic estimate			
Pubic hair	2·0	2·1	1·1	2·0
Inguinal canal ..	0·2	0·2	0·3	0·1
Voice	—	—	—	—
Axillary hair	1·0	1·0	0·8	1·0
	(*b*) Probit estimate			
Pubic hair	1·7	1·8	1·6	2·0
Inguinal canal ..	0·1	0·1	0·2	0
Voice	1·2	(0·9)	1·0	1·0
Axillary hair	1·2	1·1	1·2	1·1

puberty. On the contrary, our data suggest a slight convergence, owing to acceleration of growth among males and retardation among females about the time of the breaking of the voice of the former and of the menarche of the latter.

The foregoing assertions merely bring into sharper focus what is common observation, namely that: (*a*) enlargement of the neck is characteristic of male sexual development; (*b*) widening of the pubic region is characteristic of the female. It might seem that a purely morphological study could furnish no information with respect to the nature of the endocrine mechanisms involved; but we can probe further if we pay due regard to indications of endocrine activity supplied by the onset of changes which antedate the differential growth of the two regions under discussion. For instance, we may separate the boys of one and the same age group into those who are respectively infantile and adult with respect to voice. We are then entitled to surmise that the mean activity of the interstitial cells of the testis in the latter exceeds that of the former. *Mutatis mutandis*, we can make a similar split with respect to the output of the relevant ovarian hormone or hormones of girls of a given age group by separating those who have attained the menarche from those who have not.

Of itself, the mere fact that the growth of an organ enters on a phase of more active growth at puberty while its growth pursues its previous course in the other sex does not prove that such acceleration is the visible sign of the activity of a hormone peculiar to the sex involved. We might equally conceive the process as one which would inevitably occur unless inhibited by a hormone peculiar to the alternate sex. However, it is possible to discriminate between these alternatives by exploiting the distinction stated in the foregoing paragraph. The fact that all boys and all girls do not show at exactly the same age the first visible indications of endocrine activity associated with their respective gonads makes it possible to associate the activity of one or other gonad with a particular type of differential growth.

The accompanying Figures (5-13)* bring this contrast into perspective. Thus a separation of the male population in successive age groups with respect to the condition of the voice or to pubic hair growth does not divide them into groups of which either conforms much more closely than the other to the female pattern of growth with respect to pelvic width (Fig. 10). On the other hand, the separation of the female population into two groups

* The dotted lines connecting the terminal points in these graphs draw attention to the fact that the class samples for the corresponding age groups are small, and the points subject to a large error of sampling.

TABLE VIII

CONTOUR OF PUBIC HAIR

	Age	Apical %	Medium %	Horizontal %	Total
Boys					
	<14	0	14·3 ±9·34	85·7 ±9·34	100·0
	14—16	16·1 ±3·8	63·4 ±5·0	20·5 ±4·2	100·0
	>16	34·4 ±8·4	34·4 ±8·4	31·2 ±8·2	100·0
	Total	18·6 ±3·3	51·9 ±4·2	29·5 ±3·9	100·0
Girls					
	<12½	0	26·3 ±10·0	73·7 ±10·0	100·0
	12½—14½	1·4 ±1·0	48·6 ± 4·2	50·0 ± 4·2	100·0
	>14½	7·8 ±7·1	45·4 ± 4·2	46·8 ± 4·1	100·0
	Total	4·3 ±1·2	45·7 ± 2·9	50·0 ± 2·9	100·0

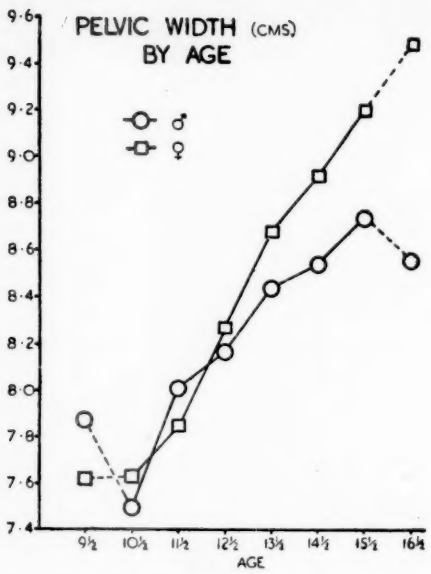

FIG. 8.

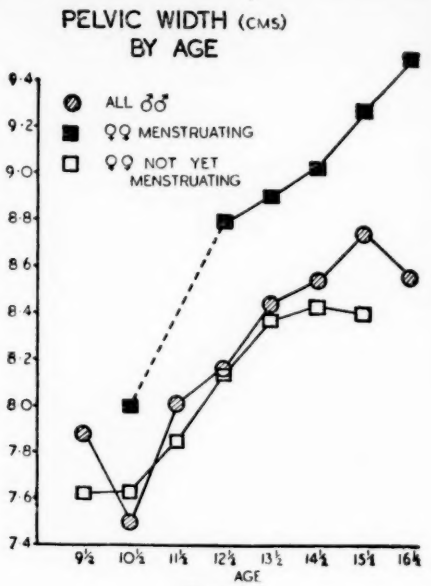

FIG. 9.

(Fig. 9) distinguished by whether they do or do not as yet menstruate isolates a group which conforms to the characteristic female growth pattern from a group which conforms to the male. Whether the testis is or is not active does not appear to be the circumstance relevant to this type of dimorphism. What is decisive is whether the female gonad has come into action. The same method of analysis (Figs. 6 and 7) throws light on the mechanism of differential growth with respect to neck girth. Before the pubic hair appears the male pursues the growth pattern of the female. The accelerated growth with respect to neck girth characteristic of puberty in the male is thus attributable to the activity of the male gonad. As regards bisacromial width, our data are less clear-cut. They suggest that the male and female gonads exercise a contrary influence on the course of growth, indicative of the separate existence of a male growth-promoting and a female growth-retarding hormone.

The conclusion that the male hormone is decisive for neck growth, and that the activity of the female gonads is decisive for the widening of the hips, does not in either case necessarily imply that the hormone involved is sex-specific. We know that castration of the male of henny-feathered poultry breeds (e.g. *Campines*) induces the assumption of cock-feathering, as does castration of the female of any breed. What would at first appear to be a qualitative distinction between the endocrine activities of the gonads may thus be merely a difference of degree. On this issue our data offer a suggestive clue. With respect to pelvic width, infantile females (Fig. 9)

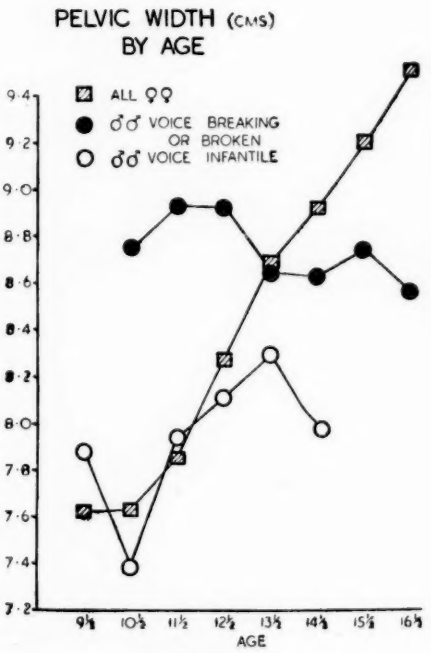

FIG. 10.

appear to be more male than the male. It would be intemperate to advance either conclusion with an air of finality. We are content to record the opinion that our data lend colour to the possibility stated above, that is, what we here call the decisive action of one or other gonad does not necessarily signify liberation of a hormone produced by that gonad alone. On the contrary, our data encourage the suspicion that the action of one or other gonad

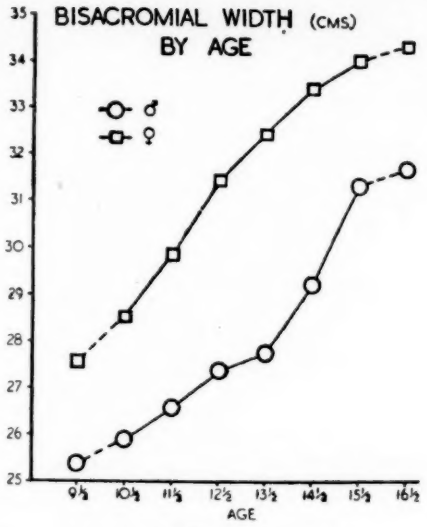

FIG. 11.

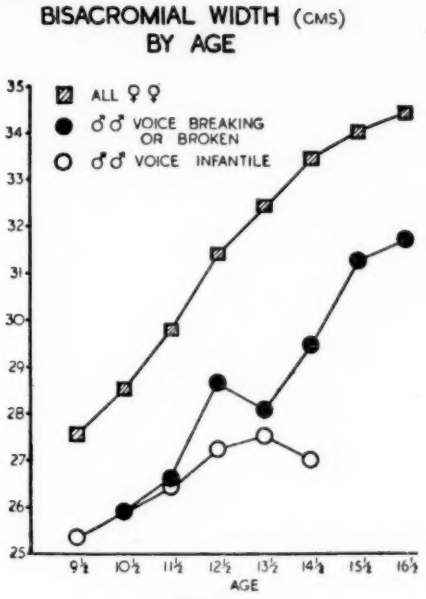

FIG. 12.

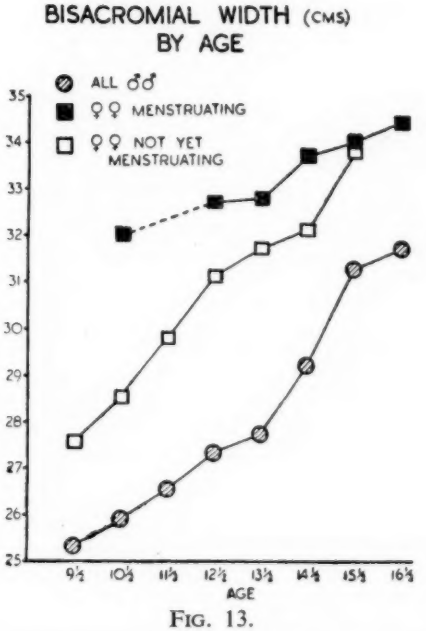

FIG. 13.

is active in a quantitative rather than a qualitative sense.

7. Relation of Physique to Pubescence

Whilst it is not our intention to attempt an evaluation of the wider issues involved in the relation between body build and sexual maturation, it is fitting at this stage to record an association which forced itself on our attention at an early stage in the examination of the crude data. The relevant evidence for this association is in Tables IV to VII. For each age group, we have separately calculated the indices exhibited in Tables II and III for each of four classes:

I A and B. The half population with height below the median stature of the same age group; and the half population with height above it;

II A and B. The half population weighing less than the median body weight of the same age group; and the half population weighing more.

For each attribute, and for both sexes, the estimated critical age with one notable exception (voice) is conspicuously later for the short than for the tall, and consistently, though less conspicuously, later for the light than for the heavy half of the population. On the other hand, there is no clear indication of an association between the duration of pubescence and stature or body weight. Whether this relation between stature or body weight on the one hand and the critical age, already noticed by Ellis (1946), is a manifestation of a genetical difference associated with body build or an indication of retardation of sexual growth associated with defective nutrition or poor health the data presented in these tables do not permit us to infer. It may indeed be that neither alternative offers a correct explanation of the difference. Acceleration of growth with respect to stature and body weight itself marks the onset of the sexual metamorphosis. Hence a sexually more differentiated sample of one and the same age group will on the whole be taller and heavier than a more infantile sample. By extracting from our total sample the taller and heavier individuals, we are in

fact extracting a sub-sample with a high proportion of individuals at a more advanced stage of sexual development in each age group. On the other hand, the data of Ellis indicate that boys who reached sexual maturity at an early date within the framework of his investigation had been relatively taller and heavier several years before its onset. In any case, we must agree with Ellis that height and weight norms exhibited without regard to the level of sexual development may be deceptive as standards for growth comparisons.

8. Contour of the Pubic Hair

It is a commonplace that the contour of the anterior margin of the pubic hair is characteristic of the sexes, and the descriptive epithets (apical and horizontal) employed in section 2 above are self-explanatory. For the entire sample of boys and girls with some pubic hair, the analysis of our data yielded the following:

	Males (%)	Females (%)
Apical ..	$18{\cdot}6 \pm 3{\cdot}3$	$4{\cdot}3 \pm 1{\cdot}2$
Intermediate ..	$51{\cdot}9 \pm 4{\cdot}23$	$45{\cdot}7 \pm 2{\cdot}9$
Horizontal ..	$29{\cdot}5 \pm 3{\cdot}87$	$50{\cdot}0 \pm 2{\cdot}9$

These figures do not show such a clear-cut differentiation as one might surmise. A threefold age split shown in Table VIII shows that the horizontal contour is more infantile. Up to the end of our age range the proportion of individuals with pubic hair of the type more characteristic of the fully grown male increases in *both* sexes.

9. Summary

Fig. 4 sufficiently summarizes the salient features concerning median ages of development with respect to axillary hair, pubic hair, voice, mammary glands, and the duration of the process of full development *vis-à-vis* the median age of the menarche (girls) and the median age of occlusion of the inguinal canal (boys). This figure is based on the mean of estimates obtained by the two methods of curve-fitting set forth in section 3. Figures 5 to 13 exhibit changes with respect to three axes of growth during the course of development, as set forth in section 6, where the possible hormonal significance of the differences exhibited is the topic of discussion.

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BOOK REVIEW

Principles of Medical Statistics. By A. BRADFORD HILL. Fourth Edition: 1948. London: *Lancet*. Pp. 252. (Price 10*s*. 6*d*.)

The appearance of a new edition of Professor Bradford Hill's manual, after three reprints of the third during the war years, is at once an indication of its successful appeal to the audience for whom the author wrote it and of a growing interest in the use of statistical methods as a tool of medical research. Its success is the more noteworthy in view of the fact that few medical schools as yet make provision for instruction of this sort as part of the undergraduate curriculum.

In the phraseology of the times, the author's aim is essentially operational. His target is to show the medical specialist without sufficient mathematical facility to appreciate their rationale, the use of statistical techniques tests to forestall unjustifiable conclusions from insufficient data and to correct unnecessary caution where confidence is permissible. Within the compass of this programme he has accomplished his task with singular lucidity. Its success owes much to a direct and unaffected style which makes for painless reading.

At a more sophisticated level of exposition, the book owes much to well-chosen illustrations of the use of elementary principles of probability. If one may regret the limitation the author has imposed on the treatment of his theme by refraining from explanations which would have made an elementary treatise a bulkier and more costly undertaking, it is one of the merits of this book that he eschews the temptation to prescribe methods the credentials of which very few research workers can hope to understand. The rationale of methods to which he does introduce the reader with little mathematical facility is within the reach of the many who will discover an unsuspected appetite for greater proficiency by digesting the fare the author offers them. Indeed one of the praiseworthy features of this book, and one which distinguishes it from so many others of its sort, is that it is unpretentious in the best sense of the term. One might illustrate this by contrast in more ways than one; but one will suffice.

There is an all too prevalent fashion among writers of elementary manuals on statistical methods to expound the latest and the least well-tried without due regard to their semantic credentials, to the limitations which those responsible for their introduction have themselves emphasized, or to the likelihood that those who apply them can ever hope to evaluate the validity of the assumptions on which they rest. In particular, it is an occasion for cynical reflection that disciples of Professor Fisher have so often chosen to overlook his own priority in recognizing that the χ^2 test for one degree of freedom and the normal difference test for a proportionate score as prescribed in Bradford Hill's book are numerically (as well as formally) identical. The modest common sense which prompts the author to refrain from introducing methods which rely on more sophisticated mathematics when methods which are relatively simple to grasp serve the same purpose is the more commendable because he addresses himself to students whose curriculum is already overburdened with authoritarian instruction.

The same common sense pervades three wholly admirable chapters devoted to discussion of common fallacies and errors. The insertion of these is no less a service to the professional statistician than to the medical student. In truth, due recognition of what statistical theory can contribute to the advance of medical science has been too long delayed by a lack of realism characteristic of many contributions which professional statisticians made in the early years of our century to anthropometry and medical sociology. The foreword appropriately recognizes a change of outlook which has come about since early controversies in Biometrika wrought so much discredit to statistical theory among medical men with their feet on the solid ground of experience. Statistics no longer needs to assert its credentials by tendencious manipulation of social data discouraging to the programme of social medicine. Medical research workers themselves recognize the value of statistical techniques to validate the conclusions suggested by their own observations.

LANCELOT HOGBEN

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